SECTION D:
SOIL ABSORPTION SYSTEMS

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A **standard system** is a technology that has proven itself over time and in many locations. Standard systems have solid research behind them and offer reasonable protection for reasonable costs. Any problems or inefficiencies of standard systems have also been clearly identified through research.

The specifications offered for standard systems are intended to provide adequate treatment of sewage with limited monitoring. Typically visual observations and evaluations of the tank are done at least once every three years.

Standard systems include **trench systems** (containing drainfield rock, gravelless pipe or chambered media), **mounds, and at-grade systems.**

Any standard system must:

- be constructed in suitable soils, see Section B
- be designed and installed with a three-foot vertical separation from high ground water, bedrock, hardpan, or other confining layer
- receive average strength septic tank effluent, defined in Section C, for high strength wastes pretreatment is required.

As-Built Drawings

After any system has been constructed, an as-built drawing should be completed by the installer and submitted to the local unit of government. See Section G pages 1 through 5.

PART I: IN-GROUND SYSTEMS

The soil treatment unit provides the final treatment and disposal of sewage tank effluent. A properly designed and installed soil treatment unit will filter out disease causing bacteria and fine solids contained in sewage tank effluent. The nutrient phosphorus will be adsorbed by (attached to) fine soil particles, and some of the nutrient nitrate-nitrogen will be converted while the remainder will move with the water.

In summer, a shallow drainfield trench supplies water (and nutrients) to grass and trees. Nitrate that remains in downward percolating water will be changed to nitrogen gas by soil bacteria or diluted by precipitation.

Lateral Trenches

As shown in Figure D-1, a lateral trench is constructed by making a level excavation 24 to 36 inches wide. The bottom of the trench must be level, as must the top of the rock in the trench.

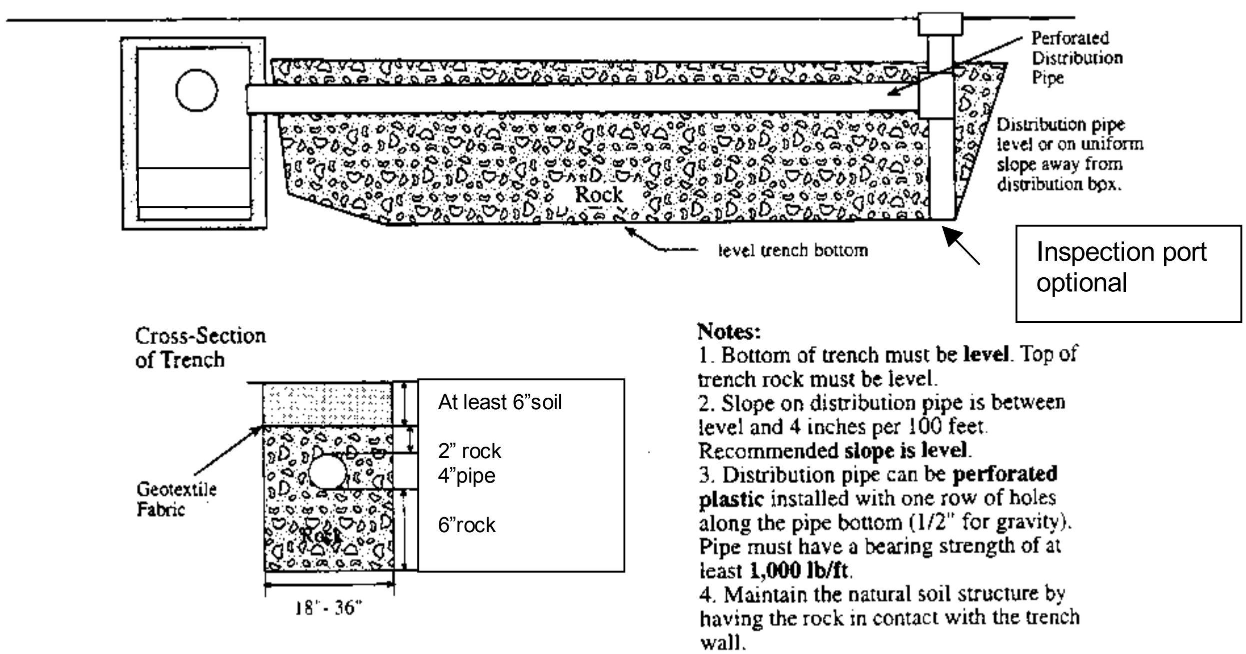


Figure D-1

Typically 6 inches of clean rock is placed in the bottom of the excavation; then a four-inch diameter perforated distribution pipe and covered with 2 inches of rock; a layer of permeable fabric is placed or the rock; and soil is backfill to a depth of six to 24 inches above the rock.

Sewage effluent flows out through the distribution pipe and down into the rock layer into the soil. Pathogens and fine sewage solids are removed by the organisms that form the biomat, a layer of bacteria and slime, that spreads the effluent across the soil surfaces of the trench and promotes aerobic conditions in the surrounding soil by limiting infiltration of the wastewater.

Soil must be neither too coarse nor too fine. A coarse soil may not adequately filter pathogens, and a fine soil may be too tight to allow water to pass through. Soils having percolation rates between 1.0 and 60 minutes per inch (mpi) or soil loading rate at or above 0.3 gpsf are suitable for treating sewage using a standard design.

Trench rock must never be placed in contact with soils having a percolation rate faster than 1.0 mpi or slower than 60 mpi. For soils with percolation rates faster than 1.0 mpi and between 61 and 120 mpi, a mound (see **Part II: Above-Ground Systems)** or a liner system, which is essentially an in-ground mound, must be used (see **Part III: Systems for Soils with Rapid Permeability).**

Standard trench systems shall not be deeper than 36-inches in depth. The final trench depth is determined by the depth of limiting layer, the bottom of the trench shall be 3-foot above the limiting layer. Studies have shown tree roots have little effect on standard systems, and that systems usually do not freeze if used on a daily basis.

System Location

Geometry, Orientation, and Configuration of the Infiltration Surface

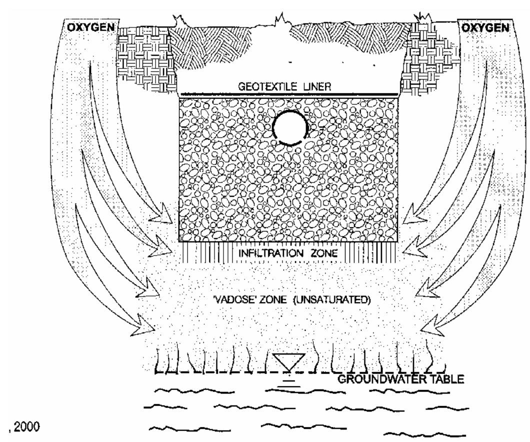
The geometry, orientation, and configuration of the infiltration surface are critical design factors that affect the performance of lateral system. They are important for promoting subsoil aeration, maintaining an acceptable separation distance from a saturated zone or restrictive horizon, and facilitating construction. The following itmes should be considered when designing a lateral system.

Geometry

The width and length of the infiltration surface are important design considerations to improve performance and limit impacts on the receiving environment. Trenches, beds, and seepage pits (or dry wells) are traditionally used geometries. Seepage pits can be effective for wastewater dispersal, but they provide little treatment because they extend deep into the soil profile, where oxygen transfer and treatment are limited and the separation distance to ground water is reduced. They are not recommended for onsite wastewater treatment and are not included as an option in this manual.

Width

Infiltration surface clogging and the resulting loss of infiltrative capacity are less where the infiltration surface is narrow. This appears to occur because reaeration of the soil below a narrow infiltration surface is more rapid. The dominant pathway for oxygen transport to the subsoil appears to be diffusion through the soil surrounding the infiltration surface, as shown below.



The saturated zone below a wide surface quickly becomes anaerobic because the rates of oxygen diffusion are too low to meet the oxygen demands of biota and organics on the infiltration surface. (Otis, 1985; Siegrist et al., 1986). Therefore, trenches perform better than beds. Typical trench widths range from 1 to 4 feet. Narrower trenches are preferred, but soil conditions and construction techniques might limit how narrow a trench can be constructed. On sloping sites, narrow trenches are a necessity because in keeping the infiltration surface level, the uphill side of the trench bottom might be excavated into a less suitable soil horizon. Wider trench infiltration surfaces have been successful in at-grades systems and mounds probably because the engineered fill material and elevation above the natural grade promote better reaeration of the fill. However, infiltration bed surface widths of greater than 10 feet are not recommended because oxygen transfer and clogging problems can occur (Converse and Tyler, 2000; Converse et al., 1990).

Length

The trench length is important where downslope linear loadings are critical, ground water quality impacts are a concern, or the potential for ground water mounding exists. In many jurisdictions, trench lengths have been limited to 100 feet. This restriction appeared in early codes written for gravity distribution systems and exists as an artifact with little or no practical basis when pressure distribution is used. Trench lengths longer than l00 feet might be necessary to minimize ground water impacts and to permit proper wastewater drainage from the site. Long trenches can be used to reduce the linear loadings on a site by spreading the wastewater loading parallel to and farther along the surface contour. With current distribution/dosing technology, materials, and construction methods, trench lengths need be limited only by what is practical or feasible on a given site. Also, use of standard trench lengths, e.g., X feet of trench/BR, is discouraged because it restricts the design options to optimize performance for a given site condition.

Height

The height of the sidewall is determined primarily by the type of porous medium used in the system, the depth of the medium needed to encase the distribution piping, and/or storage requirements for peak flows. Because the sidewall is not included as an active infiltration surface in sizing the infiltration area, the height of

the sidewall can be minimized to keep the infiltration surface high in the soil profile. A height of 6 inches is usually sufficient for most porous aggregate applications. Use of a gravelless system requires a separate analysis to determine the height based on whether it is an aggregate-free (empty chamber) design or one that substitutes a lightweight aggregate for washed gravel or crushed stone.

Orientation

Orientation of the infiltration surface(s) becomes an important consideration on sloping sites, sites with shallow soils over a restrictive horizon or saturated zone, and small or irregularly shaped lots. The long axes of trenches should be aligned parallel to the ground surface contours to reduce linear contour hydraulic loadings and ground water mounding potential. In some cases, ground water or restrictive horizon contours may differ from surface contours because of surface grading or the soil’s morphological history. Where this occurs, consideration should be given to aligning the trenches with the contours of the limiting condition rather than those of the surface. Extending the trenches perpendicular to the ground water gradient reduces the mass loadings per unit area by creating a “line” source rather than a “point” source along the contour. However, the designer must recognize that the depth of the trenches and the soil horizon in which the infiltration surface is placed will vary across the system. Any adverse impacts this might have on system performance should be mitigated through design adjustments.

Configuration

The spacing of multiple trenches constructed parallel to one another is determined by the soil characteristics and the method of construction. The sidewall-to-sidewall spacing must be sufficient to enable construction without damage to the adjacent trenches. Only in very tight soils will normally used spacings be inadequate because of high soil wetness and capillary fringe effects, which can limit oxygen transfer. It is important to note that the sum of the hydraulic loadings to one or more trenches or beds per each unit of contour length (when projected downslope) must not exceed the estimated maximum contour loading for the site. Also, the finer (tighter) the soil, the greater the trench spacing should be to provide sufficient oxygen transfer. Quantitative data are lacking, but Camp (1985) reported a lateral impact of more than 2.0 meters in a clay soil.

Given the advantages of lightweight gravelless systems in terms of potentially reduced damage to the site's hydraulic capacity, parallel trenches may physically be placed close together, but the downslope hydraulic capacity of the site and the natural oxygen diffusion capacity of the soil cannot be exceeded.

Locate the soil treatment system where a good grass cover can be established. To prevent soil compaction, do not allow automobiles or other vehicles onto the soil treatment area (lawn mowers are necessary and will not cause problems). Soil compaction causes problems both for oxygen transfer and water movement.

Locate the soil treatment system so that it is not subjected to surface water runoff. Do not allow runoff from roofs, patios, driveways or other paved areas to flow across the area over the soil treatment unit. Construct a small diversion or grassed waterway on the upslope side of the area and lead the excess surface water away from the soil treatment unit. Establish a grass cover as soon as possible after installation to prevent erosion and to promote evapotranspiration during the growing season.

Figure D-2 shows minimum depths and separation requirements for drainfield trenches. At least three feet of soil suitable for treatment must be located below the bottom of the trench. The minimum rock depth under the distribution pipe is six inches and two inches of rock must cover the distribution pipe. Minimum soil cover is six inches, so that the total distance from the seasonally saturated or impervious layer to the final grade is 4.5 feet. Note that this total could be made up of 3.5 feet of original soil and one foot of fill soil over the piping of the system.

From the USEPA Onsite wastewater Treatment Systems Manual

Chapter 4: Treatment Processes and Systems

Table 4-4. Geometry, orientation, and configuration considerations for SWISs

Design type	Design considerations
Trench	
Geometry	
Width	Preferably less than 3 ft. Design width is affected by distribution method, constructability, and available area.
Length	Restricted by available length parallel to site contour, distribution method, and distribution network design.
Sidewall height	Sidewalls are not considered an active infiltration surface. Minimum height is that needed to encase the distribution piping or to meet peak flow storage requirements.
Orientation/ configuration	Should be constructed parallel to site contours and/or water table or restrictive layer contours. Should not exceed the site's maximum linear hydraulic loading rate per unit of length. Spacing of multiple, parallel trenches is also limited by the construction method and slow dispersion from the trenches.
Bed	
Geometry	
Width	Should be as narrow as possible. Beds wider than 10 to 15 feet should be avoided.
Length	Restricted by available length parallel to site contour, distribution method, and distribution network design.
Sidewall height	Sidewalls are not considered an active infiltration surface. Minimum height is that needed to encase the distribution piping or to meet peak flow storage requirements.
Orientation/ configuration	Should be constructed parallel to site contours and/or water table or restrictive layer contours. The loading over the total projected width should not exceed the estimated downslope maximum linear hydraulic loading.
Seepage pit	Not recommended because of limited treatment capability.

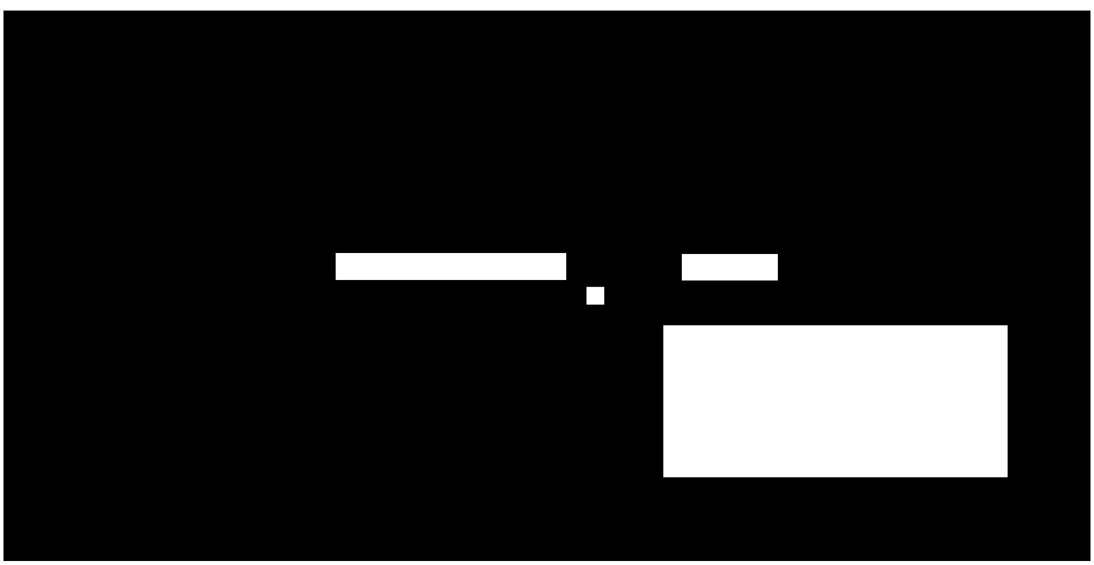
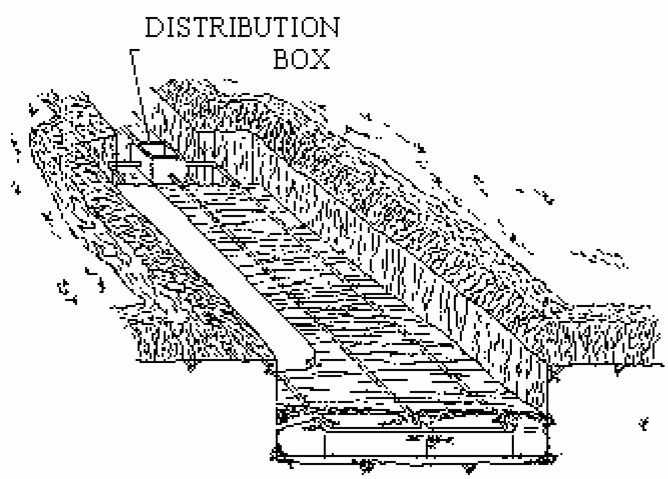


Figure D-2

Absorption Beds

A typical layout of an absorption bed is shown in Figure D-3. A trained professional should design absorption beds. Any excavation wider than three feet may considered a absorption bed. Figure D-3 shows a perspective view of absorption bed construction details.

Absorption beds should be constructed to be as narrow as possible and should be pressure dosed. Beds that are wide and gravity fed will tend to pond water , become anaerobic and proper treatment will not occur.



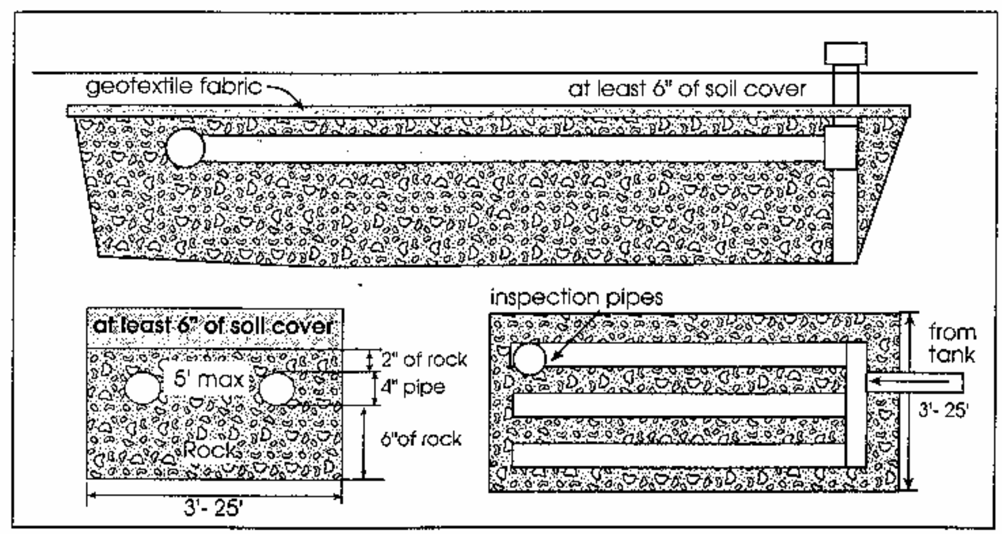


Figure D-3

Typically in a gravity system very little effluent is distributed through the distribution pipe. Effluent flows through the holes in the first length of pipe and into the clean rock, and distributes itself over the soil surface area to the extent of the biomat.

The construction of a seepage bed is essentially the same as that for a trench, except that the bed is wider.

Pressure distribution must be used for all seepage beds where the soil percolation rate is 0.1 to 5 mpi or greater than 1.0 gpsf or where the soil has a medium sand texture or coarser. If pressure distribution is used the bed may be sized as if for trenches.

Distribution Media

Drainfield Rock

Gravelless Wastewater Dispersal Systems

Gravelless systems have been widely used. They take many forms, including open-bottomed chambers, fabric-wrapped pipe, and synthetic materials such as expanded polystyrene foam chips. Some gravelless drain field systems use large-diameter corrugated plastic tubing covered with permeable nylon filter fabric not surrounded by gravel or rock. The area of fabric in contact with the soil provides the surface for the septic tank effluent to infiltrate the soil. The pipe is a minimum of 10 to 12 inches in diameter covered with spun bonded nylon filter fabric to distribute water around the pipe. The pipe is placed in a 12- to 24-inch wide trench. These systems can be installed in areas with steep slopes with small equipment and in hand-dug trenches where conventional gravel systems would not be possible.

Reduced sizing of the infiltration surface is often promoted as another advantage of the gravelless system. This is based primarily on the premise that gravelless systems do not "mask" the infiltration surface as gravel does where the gravel is in direct contact with the soil. Proponents of this theory claim that an infiltration surface area reduction of 50 percent is warranted. However, these reductions are not based on scientific evidence though they have been codified in some jurisdictions (Amerson et al., 1991; Anderson et al., 1985; Carlile and Osborne, 1982; Effert and Cashell, 1987). Although gravel masking might occur in porous medium applications, reducing the infiltration surface area for gravellesss systems increases the BOD mass loading to the available infiltration surface. Many soils might not be able to support the higher organic loading and, as a result, more severe soil clogging and greater penetration of pollutants into the vadose zone and ground water can occur (University of Wisconsin, 1978), negating the benefits of the gravelless surface.

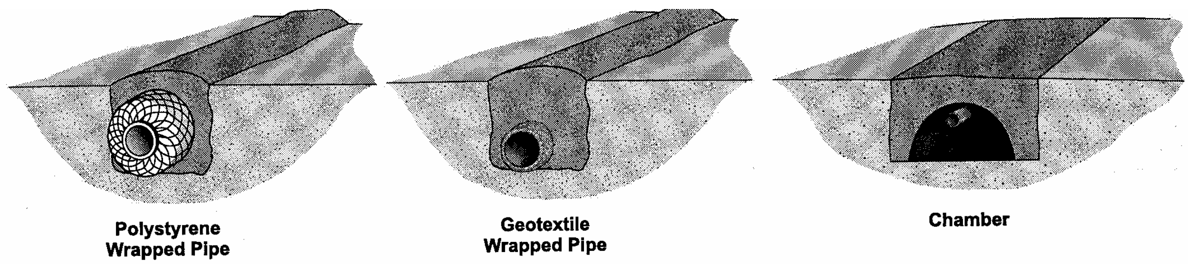
A similar approach must be taken with any contaminant in the pretreatment system effluent that must be removed before it reaches ground water or nearby surface waters. A 50 percent reduction in infiltrative surface area will likely result in less removal of BOD, pathogens, and other contaminants in the vadose zone and increase the presence and concentrations of contaminants in effluent plumes. The relatively confined travel path of a plume proves fewer adsorption sites for removal of adsorbable contaminants (e.g., metal, phosphorus, toxic organics). Because any potential reductions in infiltrative surface area must be analyzed in a similar comprehensive fashion, the use of gravelless medium should be treated similarly to potential reductions from increased pretreatment and better distribution and dosing concepts.

Despite the cautions stated above, the overall inherent value of lightweight gravelless systems should not be ignored, especially in areas where gravel is expensive and at sites that have soils that are susceptible to smearing or other structural damage during construction due to the impacts of heavy machinery on the site. In all applications where gravel is used (see *SWIS Media* in the following section), it must be properly graded and washed. Improperly washed gravel can contribute fines and other material that can plug voids in the infiltrative surface and reduce hydraulic capability. Gravel that is embedded into clay or fine soils during placement can have the same effect.

Gravelless Distribution Medium

The idea of using something other than rock to hold the trenches apart is not new: gravelless trenches have been used in Texas since 1971. The gravelless trench has since then been shown to be a good option for onsite sewage treatment in Iowa. As a result, it has been adopted as a standard system.

There are several options for gravelless systems. The first is gravelless pipe, which is corrugated pipe surrounded by a synthetic fabric. The second is a chamber made out of a nondegradable material, typically plastic, used to hold the soil apart. The third is a new product using expanded polystrene wraped around a plastic pipe.



Source: National Small Flows Clearinghouse.

USEPA Onsite Wastewater Treatment Systems Manual *4-21*

Gravelless Pipe Systems

Gravelless pipe is a corrugated pipe wrapped in synthetic fabric used in place of gravel for a trench system. This pipe typically has an inside diameter of eight to ten inches. The corrugations are usually 1/2-inch, with 3/4-inch separations.

Gravelless pipe systems are conventional because the rock that traditionally separates trenches provides little or no treatment of the effluent prior to its being dispersed into the soil. Any system that holds the soil apart and allows the wastewater to come in contact with the soil should be acceptable, as long as it has an established loading rate, or the area of soil contact can be easily determined.

Gravelless pipe systems are designed to be surrounded by soil. Do not backfill the excavation with drainfield rock. If an excavation has been filled with rock around the pipe, the biomat will not develop at the pipe-rock interface, but will instead develop at the rock-soil interface. Follow the manufacturers' recommendations for installation. (See Figure D-4.)

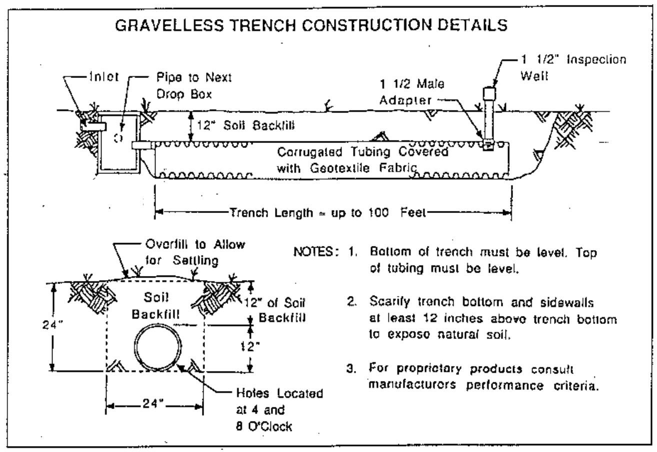


Figure D-4

Gravelless pipe systems have advantages:

- They can be relatively shallow.
- They are easy to handle, deliver, lay out, and install.
- They are lightweight and can be carried into remote, difficult-to-reach sites.
- Little cleanup is required after installation.
- They can be installed on a steep slope because of the minimal amount of equipment necessary for installation.
- Material is consistently sized.
- No rock

They also have disadvantages.

- Only 2 sizes exist, 8” & 10”.
- Problems can occur in areas of fine sand.
- Cost of materials varies; these systems can be comparatively expensive.
- Fabric plugging.

Potential Problems with Gravelless Pipe.

The utilization of gravelless pipe in fine sands have been found to develop a slower long-term acceptance rate, even though they have the same permeability and water flow characteristics as medium sand. During field reviews, this problem has been noted most often with fine sand. The key to installing gravelless pipe systems that work in fine sand is sizing them properly.

In some areas of Iowa, fabric plugging was the suspected cause of failure in soils other than fine sand, however there has been no research to document the cause of the failure.

Keep these two major construction guidelines in mind:

- **Keep it dry.** These materials will not overcome the plastic limit in soils.
- **Keep it level.** It is critical that the pipe be laid level. Most manufacturers place a stripe on the top of the pipe to allow even leveling of the product and alignment of the holes.

A gravelless pipe system must be supported all the way around during backfilling. If the pipe is too tight in the trench and space is not filled with soil during backfilling, the system will compress and failure can come very quickly. With adequate pipe support and a good base, such problems will not occur.

Chamber Systems

The chamber system is another technology that uses something other than gravel to fill the trenches. A number of chamber systems have been developed out of plastic materials, typically featuring a plastic dome with holes or slots (or both) cut in the sides. (See Figure D-5.)

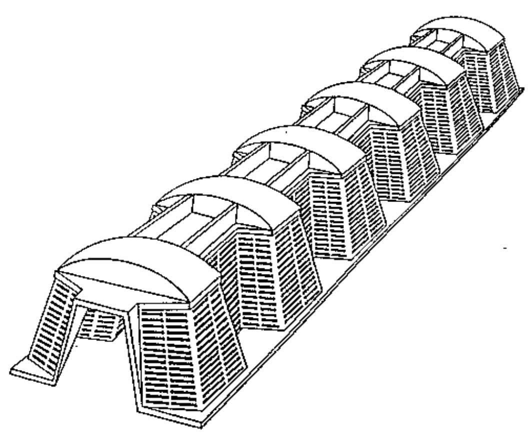


Figure D-5

A leaching chamber is a wastewater treatment system that consists of trenches or beds and one or more distribution pipes or open-bottomed plastic chambers. Leaching chambers have two key functions: to disperse the effluent from septic tanks and to distribute this effluent throughout the trenches. A typical leaching chamber consists of several high-density polyethylene injection-molded arch-shaped chamber segments. A typical chamber has an average inside width of 15 to 40 inches (38 to 102 centimeters) and an overall length of 6 to 8 feet (1.8 to 2.4 meters). The chamber segments are usually 1-foot high, with wide slotted sidewalls. Depending on the drain field size requirements, one or more chambers are typically connected to form an underground drain field network.

Typical leaching chambers are gravelless systems that have drain field chambers with no bottoms and plastic chamber sidewalls, available in a variety of shapes and sizes. Use of these systems sometimes decreases overall drain field costs and may reduce the number of trees that must be removed from the drain field lot.

About 750,000 chamber systems have been installed over the past 15 years. Currently, a high percentage of new construction applications use lightweight plastic leaching chambers for new wastewater treatment systems in states like Colorado, Idaho, North Carolina, Georgia, Florida, and Oregon. The gravel aggregate traditionally used in drain fields can have large quantities of mineral fines that also clog or block soil pores. Use of leaching chambers avoids this

problem. Recent research sponsored by manufacturers shows promising results to support reduction in sizing of drain fields through the use of leaching chambers without increased hydraulic and pollutant penetration failures (Colorado School of Mines, 201; Siegrist and Vancuyk, 2001a, 2001b). These studies should be continued to eventually yield rational guidelines for proper sizing of these systems based on the type of pretreatment effluent to be received (septic tank effluent, effluent from filters or aerobic treatment units, etc.), as well as different soil types and hydrogeological conditions. Many states offer drain field sizing reduction allowances when leaching chambers are used instead of conventional gravel drain fields.

Because leaching chamber systems can be installed without heavy equipment, they are easy to install and repair. These high-capacity, open-bottom drain field systems can provide greater storage than conventional gravel systems and can be used in areas appropriate for gravel aggregate drain fields. Leaching systems can operate independently and require little day-to-day maintenance. Their maintenance requirements are comparable to those of aggregate trench systems.

The lightweight chamber segments available on the market stack together compactly for efficient transport. Some chambers interlock with ribs without fasteners, cutting installation time by more than 50 percent reused and conventional gravel/pipe systems. Such systems can be reused and relocated if the site owner decides to build on another drain field site. A key disadvantage of leaching chambers compared to gravel drain fields is that they can be more expensive if a low-cost source of gravel is readily available.

Porous media should be placed along the chamber sidewall area to a minimum compacted height of 8 inches above the trench bottom. Additional backfill is placed to a minimum compacted height of 6 to 12 inches above the chamber, depending on the chamber strength. Individual chamber trench bottoms should be leveled in all directions and follow the contour of the ground surface elevation without any dams of other water stops. The manufacturer's installation instructions should be followed and systems should be installed by an authorized contractor.

Chambered systems have a number of advantages:

- Light weight,
- ease of installation,
- open bottom.
- more storage capacity for peak flows, and

Disadvantages:

- Less horizontal flexibility,
- wide chambers may crush without adequate soil cover.

Expanded Polystyrene (EPS) drainfield systems

The following information is on a new product. At the time of this publication this product was not listed in Chapter 69, therefore each County will need to determine the suitability of this product.

EPS systems consist of one or more cylindrical bundles that are typically 12 inches in diameter. The bundles are typically produced in 5-foot or 10-foot long sections and are comprised of a four-inch corrugated polyethylene pipe surrounded by small, specifically engineered EPS pieces. The perimeter of the bundle is formed by a flexible and open netting made of polyethylene. When numerous bundles are used as part of a particular drainage product, typically only one of the bundles contains a four-inch pipe while the other bundles contain only the EPS pieces surrounded by the netting.

Two of the major concerns typically voiced concerning EPS systems surround the strength of EPS and the effects of chemicals on EPS. Independent load tests have shown that EPS systems can withstand tremendous loads such as an AASHTO rated H10 load test without compromising the structural properties of the EPS system. Much research has been performed over the past few decades concerning the effects of chemicals on EPS. It has been numerously concluded that normal household cleaners and solvents will not be detrimental to the structural properties of EPS. Deterioration of EPS will only occur if the product is subjected to large amounts of undiluted hydrocarbons such as diesel fuel or by long term exposure to direct UV.

EPS system advantages

- Lightweight and easy to install
- Extreme flexibility without any fittings
- Very cost effective

EPS system disadvantages

- Bulkier product than other alternative drainfield products
- Top of product must be covered with a barrier to eliminate soil intrusion
- Use in Iowa has been limited at the time of this publication

Effluent Distribution Devices

There are several types of “distribution” boxes: drop boxes, distribution boxes, and valve boxes.

Distribution Boxes

Distribution boxes use gravity to equally divide the septic tank effluent to the trenches/laterals. The wastewater flows from the septic tank into the distribution box. The box must be level and made of plastic or polyethylene. A leveling device placed in each outlet is required to distribute the flow equally to all outlet pipes. The wastewater flows by gravity in watertight pipes to the trenches/laterals.

Because distribution boxes are designed to distribute the wastewater equally, all trenches must be the same length and should be able to treat a like amount of effluent. The outlet pipes from the distribution box should have equal slopes for five feet after leaving the box. Figure D-6 shows the layout of a trench system using a distribution box.

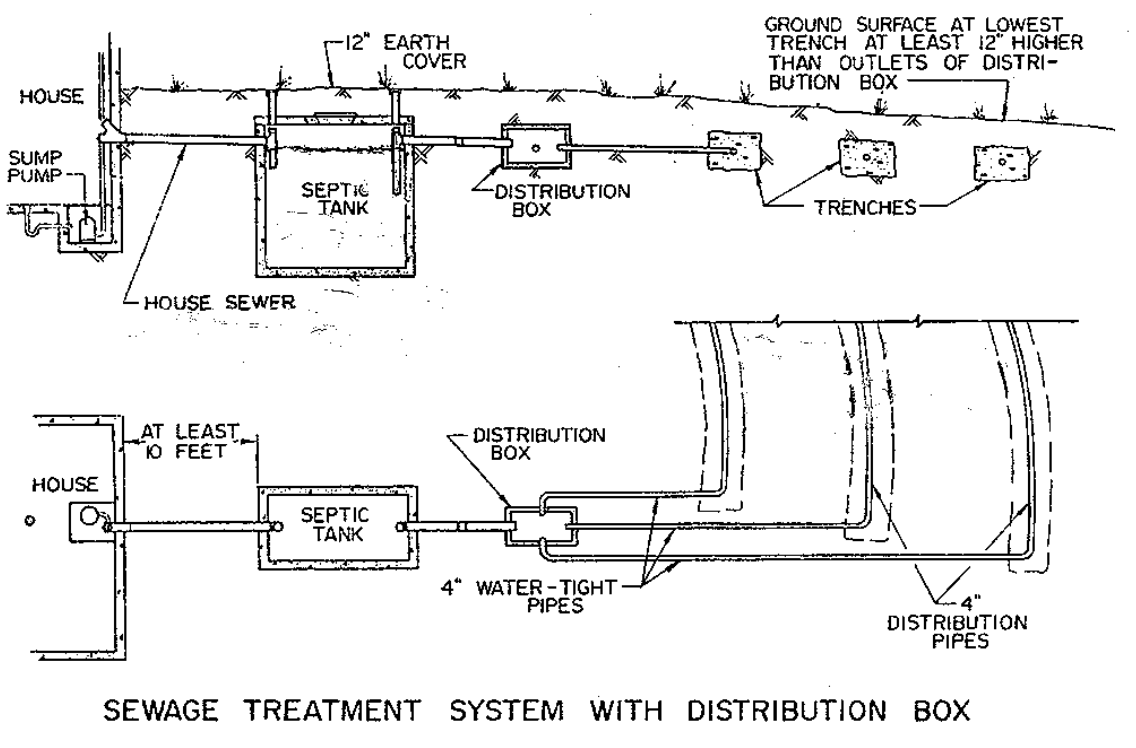


Figure D-6

Designing Laterals Using Distribution Boxes

When using distribution boxes, the trench is not filled with water and only the bottom area of the trench is used to calculate the length of lateral needed.

In conflict with what is allowed in Chapter 69, when using a distribution box there should be no reduction in bottom area for using more than 6-inches of rock under pipe. The side wall area is not exposed to the water for absorption. The only time the side wall is exposed to water is when the bottom of the trench is plugged and water is ponding in the trench. When this happens the lateral system failing. This does not hold true when using drop boxes.

When a **percolation test** is used to determine soil loading rate refer to Chapter 69 for the length required.

When using the **soil evaluation** method the soil loading rate is used to calculate the length of trench needed. Here are several examples for different types of laterals. Only the bottom surface area is used to calculate the length of trench.

Conventional 4-inch lateral pipe and 6-inches of rock.

Example: 3-bedroom home, 450-gpd flow, loamy soil, loading rate 0.6 gpsf.
24-inch wide trench with 6-inches of rock below pipe.

450 ÷ 0.6 = 750 SF (bottom area needed)
750 ÷ 2 ft wide trench = 375 feet of trench

36-inch wide trench with 6-inches of rock below pipe.

450 ÷ 0.6 = 750 SF (bottom area)
750 ÷ 3.0 ft wide trench = 250 LF pipe

Chamber System Design

The length of Chamber is based upon exposed bottom trench area, soil loading rate, and wastewater flow. No credit is given for masking affects.

Example: 3-bedroom home, 450-gpd flow, loamy soil, loading rate 0.6 gpsf.
36-inch wide Chamber:

450 ÷ 0.6 = 750 SF (bottom area)
750 ÷ 3.0 = 250 LF of Chamber pipe

If Infiltrator ® EQ-24 is used

Base width is 15-inches. This Chamber is less than ½ the width of the 36-wide Chamber:

450 ÷ 0.6 = 750 SF (bottom area)
750 ÷ (15 ÷ 12) = 600 LF of Chamber pipe EQ-24

Gravelless Pipe System Design with Distribution Boxes

There is much debate over the amount of surface area that is utilized when distribution boxes and gravelless pipe are used because the pipe is not full of water and the surface area is difficult to measure. Water may wick around the fabric to wet the entire surface of the pipe. The designer should consider this when designing these types of systems.

Chapter 69 states the 10-inch gravelless is equivalent to 24-inch wide rock system therefore the equivalent bottom area would be 24-inches.

Example: 3-bedroom home, 450-gpd flow, loamy soil, loading rate 0.6 gpsf.

450 ÷ 0.6 = 750 SF bottom trench area
750 ÷ 2 = 375 LF of pipe.

Chapter 69 states that 8-inch gravelless pipe is not equivalent to a 24-inch wide trench with 6-inches of rock and that a 20% increase in length is required.

Example: 3-bedroom home, 450-gpd flow, loamy soil, loading rate 0.6 gpsf:

450 ÷ 0.6 = 750 SF bottom trench area
750 ÷ 2 = 375 LF of pipe.
For 8-inch gravelless pipe 375 x 1.20 = 450 LF of pipe

Drop Boxes

Drop boxes are used to achieve serial distribution. Sewage is distributed by gravity flow that loads one lateral to a predetermined level before overflowing to the next lateral; each length of lateral is flooded before the next lateral is flooded.

Figures D-7, D-8 & D-9 shows the layout of a sewage treatment system using drop box distribution. Effluent flows through a watertight pipe from the septic tank to the first drop box. Outlets near the bottom of the drop box connect to the distribution pipe of the trenches. Another outlet near the top of the drop box connects to a watertight pipe leading to the drop box of the next trench.

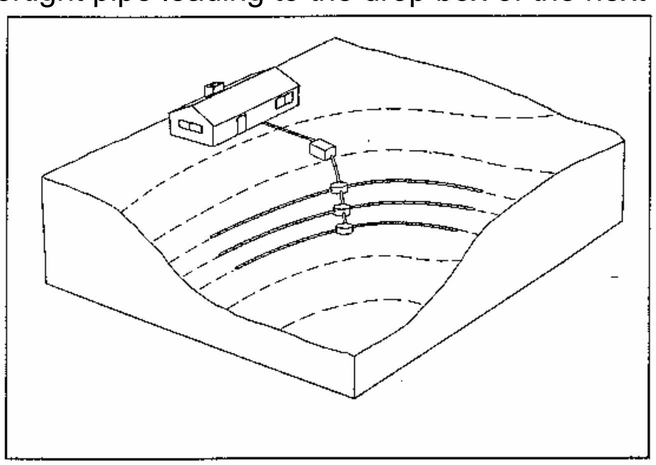


Figure D-7

The inlet pipe to the drop box should be one inch higher than the outlet pipe leading to the next drop box. When sewage tank effluent is delivered to the drop box by a pump, the inlet will be directed so the effluent flows against a side of the box that does not have an outlet. A detailed view of the drop box is shown in Figure D-8.

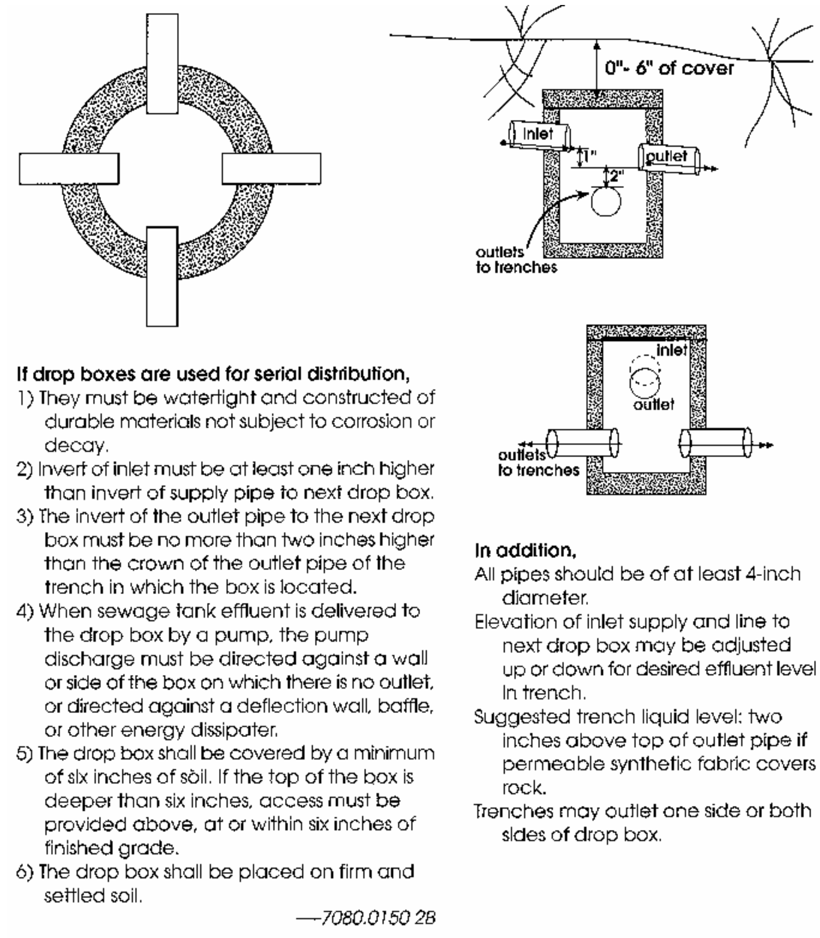


Figure D-8

Drop boxes typically are installed for each lateral line. Some systems use an overflow at the end of the lateral line to flow water into the next lateral. In addition to providing for loading of the soil absorption area, drop boxes also allow inspection of the system. Drop boxes may be constructed of fiberglass or polyethylene. Drop box strength is a factor to consider when backfilling the sewage system.

The liquid level in a trench is established by the elevation of the supply line pipe leading to the next drop box. If the elevation of the bottom of the supply pipe is approximately at the top of the rock in the trench, this liquid level will utilize the entire trench sidewall, develop the maximum hydraulic head on the bottom of the trench, and maximize evapotranspiration.

When the first trench is treating effluent at its long-term acceptance rate, any additional effluent will flow to the drop box of the second trench. Only that portion of the soil treatment unit required to treat the effluent is used. Not all trenches should be full of water. If all of the trenches are full of water then, either the system was under designed, the system is at or near failure. In either case additional laterals should be added.

The rate at which sewage is generated and the rate at which soil will absorb effluent will vary throughout the year. A change in the number of people using a system will affect the daily sewage flow. High soil moisture conditions will decrease the rate at which the soil will absorb effluent, while hot, dry weather will increase the ability of the soil to accept effluent.

Less trench bottom area will be required during summer when the soil is dry due to evapotranspiration than during winter when evapotranspiration is negligible. Thus, the trench bottom area not being used will automatically rest and dry out. This resting and drying will increase the soil's ability to absorb effluent.

The homeowner or an onsite professional can manage the drop box system. To rest the system, plug or cap the outlet pipe from the first box. The effluent will then flow into the second drop box, bypassing the first trench. The first trench will "rest:" the infiltrative surface will recover its ability to accept and treat wastewater.

If surface seepage occurs with a drop box system, typically all of the laterals are full of water and the system is being used at greater than its capacity. In this case, the seepage will occur typically at the lowest trench or weakest soil condition. To solve the problem, additional drainfield trench area will need to be constructed.

Additional trenches may be easily added to a drop box system if increased daily sewage flow requires them, provided more area of suitable soil exists. As shown in Figure D-9, a watertight pipe is connected to the last drop box of the existing system and additional drop boxes and trenches can be added without disturbing the existing sewage treatment system.

Note laterals may of different lengths but not over 100 feet.

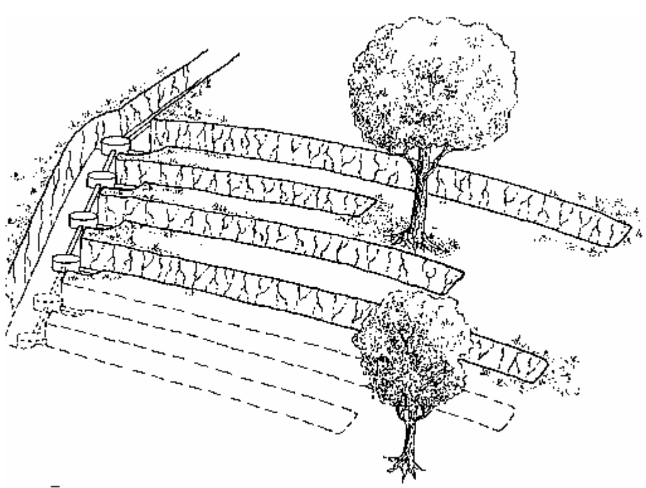


Figure D-9

The drop box provides a convenient point for inspecting the soil treatment unit. The drop box cover can be installed at the ground surface or covered with four to six inches of soil to prevent unauthorized entry. Opening the drop boxes will show how much of the drainfield trench system is being used. Some manufactures make a drop box with an inspection port.

An elevation difference of two inches between successive trenches is all that is needed for the installation of drop boxes. The first inch is for the elevation difference between the inlet pipe and the supply pipe to the next drop box, and the second inch is for the slope of the supply pipe to the next drop box. Because of this drop requirement level sites may not be appropriate for drop boxes.

Designing Laterals Using Drop Boxes

When using drop boxes, the trench is filled with water, again only the bottom area of the trench is used to calculate the square footage based on the soil loading rate and wastewater design flow, or percolation rate and Chapter 69.

If the soil is suitable and there are no confining layer conflicts, increasing the depth of rock to greater than the required 6-inches will increase the soil water soil-water contact area. In this case, the total bottom area square footage may be reduced. This reduction should only be used on confined space lots where adequate space is an issue. There is additional risk of failure by reducing the square footage of trench. For rock trenches, the total bottom square footage area may be reduced as follows:

Example: 3-bedroom home, 450-gpd flow, loamy soil, loading rate 0.6 gpsf.

> 24-inch wide trench with 6-inches rock below pipe. There is no reduction for 6 inches of rock.
>
> 450 ÷ 0.6 = 750 SF (bottom area)
> 750 ÷ 2 ft wide trench = 375 feet of trench
>
> If confined space/lot conditions exist and reducing the lateral length is the only practical solution, then follow may alpply:
>
> Assume above conditions and 24-inch wide trench with 12-inches rock below pipe.

Chapter 69 allows a 20% reduction in length for 12-inches of rock.
375 x 0.80 (80% of length) = 300 feet of trench

For other extra rock conditions:
for 12-inches of rock = 20% reduction
for 18-inches of rock = 34% reduction
for 24-inches of rock = 40% reduction

Chamber and Gravelless systems do not use rock and there is no reduction for use of rock with these systems.

These reductions should not be used for systems using distribution boxes.

Chamber System and Gravelless Pipe System Design with Drop Boxes

The length of a lateral is based upon the exposed bottom trench area, the soil loading rate and/or percolation test, and the daily wastewater flow.

Valve Boxes

Valve boxes, are another distribution option. Valve boxes have valves that open and close the outlets. Valve boxes are most commonly used to divert the flow from one lateral to the other by alternating the valves.

Curtain Drain

Subsurface Drainage

Soils with shallow saturated zones sometimes can be drained to allow the infiltration surface to be placed in the natural soil. Curtain drains, vertical drains, underdrains, and mechanically assisted commercial systems can be used to drain shallow water tables or perched saturated zones. Of the three, curtain drains are most often used in onsite wastewater systems to any great extent. They can be used effectively to remove water that is perched over a slowly permeable horizon on a sloping site. However, poorly drained soils often indicate other soil and site limitations that improved drainage alone will not overcome, so the use of drainage enhancements must be carefully considered. Any sloping site that is subject to frequent inundation during prolonged rainfall should be considered a candidate for upslope curtain drains to maintain unsaturated conditions in the vadose zone.

Curtain drains are installed upslope of the laterals to intercept the permanent and perched ground water flowing through the site over a restrictive horizon. Perforated pipe is laid in the bottom of upslope trenches excavated into the restrictive horizon. A durable, porous medium is placed around the piping and up to a level above the estimated seasonally high saturated zone. The porous medium intercepts the ground water and conveys it to the drainage pipe. To provide an outfall for the drain, one or both ends of the pipe are extended downslope to a point where it intercepts the ground surface. When drainage enhancements are used, the outlet and boundary conditions must be carefully evaluated to protect local water quality.

The drain should avoid capture of the lateral percolate plume and ground water infiltrating from below the lateral or near the end of the drain. A separation distance between the lateral and the drain that is sufficient to prevent percolate from the lateral from entering the drain should be maintained. The vertical distance between the bottom of the lateral and the drain and soil permeability characteristics should determine this distance. As the vertical distance increases and the permeability decreases, the necessary separation distance increases. A 10-foot separation is used for most applications. Also, if both ends of the drain

cannot be extended to the ground surface, the upslope end should be extended some distance along the surface contour beyond the end of the lateral. If not

done, ground water that seeps around the end of the drain can render the drain ineffective. Similar cautions should be observed when designing and locating outlet locations for commercial systems on flat sites. The design of a curtain drain is based on the permeability of the soil in the saturated zone, the size of the area upslope of the lateral that contributes water to the saturated zone, the gradient of the drainage pipe, and a suitable outlet configuration. If the saturated hydraulic conductivity is low and the drainage porosity (the percentage of pore space drained when the soil is at field capacity) is small, even effectively designed curtain drains might have limited effect on soil wetness conditions. Penninger at al. (1998) illustrated this at a site with a silty clay loam soil at field capacity that became completely re-saturated with as little as 1-inch of precipitation. Figure 4-6 provides a useful design chart that considers most of these parameters. For further design guidance, refer to the U. S. Department of Agriculture's *Drainage of Agricultural Land (*USDA, 1973).

A curtain drain, illustrated in Figure D-10, may be used to remove excess soil water moving laterally along a slope.

This manual recommends contacting an engineer, geologist, soil scientist, or NRCS for assistance when designing a curtain drain system.

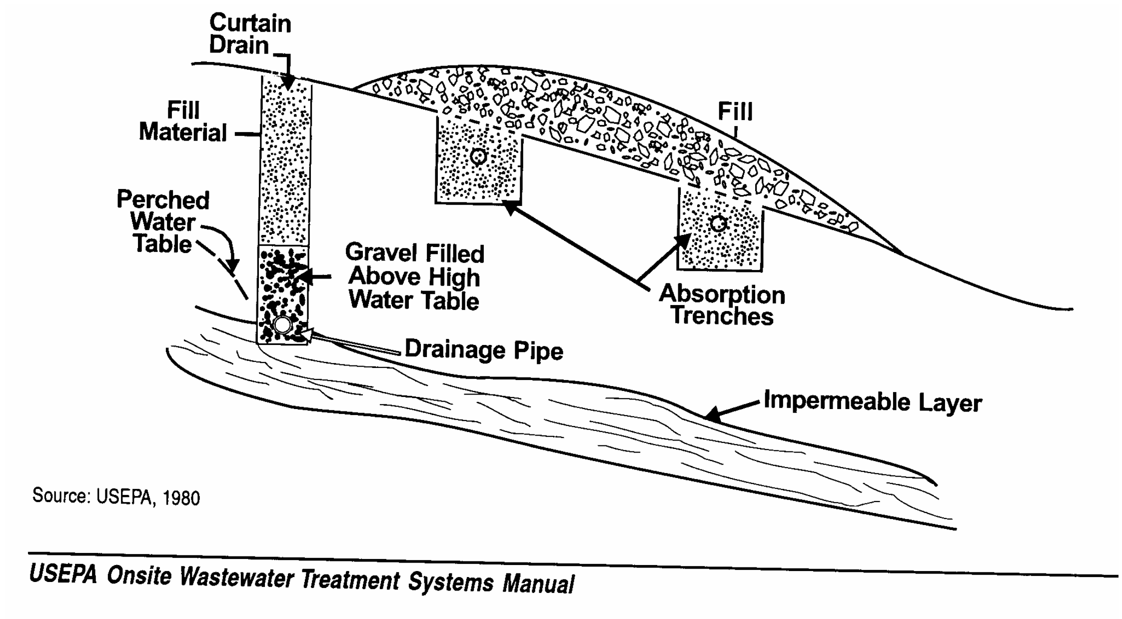


Figure D-10

Interceptor Drains or Curtain Drains

These drains may also be useful in areas of seasonally high water tables. They should be located uphill and on adjacent sides of the drainfield with at least ten feet of undisturbed soil between the sidewall of the soil treatment unit and the draintile. Within shorelands of public waters, draintile may be used, provided the groundwater table has a slope of at least two feet per 100 feet toward the public water. At least 10 feet of undisturbed soil should exist between the sidewall of the soil treatment unit and the draintile.

Backfill: The trench should be at least six inches wider than the outside diameter of the tile. An envelope of pea gravel or other approved clean pit-run gravel should be placed around the tile. The same material, or clean or washed sand, should be used to backfill the trench to within one to two feet of the top of the trench. Drain material should not be used downstream from the site in those parts of the drain that are not required to intercept groundwater.

Slope: The tile line grade should be no flatter than 1-1/4 inches per 100 feet (0.1 percent). The inside diameter of the pipe should be no smaller than four inches. Most installations will not require a size larger than four inches in diameter.

Tile Connections: The curtain drain may be connected to an existing tile drain when depth and grade permit and when approved by the local government unit. A factory-manufactured tee or Y should be used to make the connection.

Outlet: When the drain must outlet on the surface, a corrugated metal pipe at least 12 feet in length with a solid animal guard or outlet gate should be used. The outlet should be located where the water can flow away from it as fast as it is discharged. There should be at least a six-inch clearance between the bottom of the outlet pipe and the surface of the ground or water beneath it. Only one outlet should be used for the curtain drain. The water must exit onto the owner's property or onto a neighboring drainage easement.

The curtain drain should be located on the sewage system plans, which should include the following information:

- elevations of the curtain drain (bottom and final top grade) with respect to the elevations of the drainfield,
- initial and proposed finished topography of the site,
- trench widths,
- spacings,
- details of conduit and drain material placement, and
- depth of drain material and cover.

Artificial Drainage

Drawdown and mounding of the water table make it difficult to determine the appropriate depth for placement of the tile to create a three-foot unsaturated zone below the system. This drawdown is similar to the cone of depression caused by a pumping well. Drainage systems are not encouraged, because of limited success with these systems.

Agricultural Draintile

Under certain conditions, the installation of agricultural draintile may be helpful. The usual purpose of agricultural draintile is not to lower the water table in a field, but instead to create a situation where that field can be plowed within 48 hours of a two-inch rain. The movement of water off a field is much different than the overall lowering of a water table.

Typical designs for a draintile system allow for saturated soil conditions to come nearly to the soil mottles, but for a shorter duration than if the tiles were not in place. Research conducted by the University of Minnesota in a large field in southern Minnesota showed that the water table will return to the level of soil mottling during the course of a wet season but will not stay there for as long as it would if that field were not tiled.

In an onsite system, this situation is not be acceptable under current rules. When groundwater comes into a mottled soil zone, if the zone is less than three feet below the system, the system would be considered to be failing. To meet the intent of the code, a system must work for 365 days a year. Some changes in draintile installation are necessary to accomplish this goal.

When draintile is used to lower the water table, a drawdown curve or zone of influence is apparent. The steepness of this curve is determined by the soil texture or soil permeability. In sandy soils, the curve will be flatter, and the area impacted will be much greater. In heavier soils, or those containing a higher percentage of clay, the slope will be steeper and the area affected will be far less than in a sandy soil.

For soils which are typically well drained, the steepness and the area impacted by the impact curve of the zone of influence of draintiles is relatively small. A zone of impact can be increased by placing the tile deeper, which can be costly and result in construction problems.

Slowly Permeable Soils

Suitable soil permeability rates for conventional systems range from 1 to 60 mpi or greater than 0.3 gpsf, in the treatment area where the system will be placed.

Slowly permeable soils with permeability rates between 60 to 120 mpi *do* provide treatment, but problems are often encountered with the dispersal of wastewater and with construction of the system. At-grade, mound, or alternative systems should be considered

60 to 120 mpi

Solutions:

- At-Grade system
- Mound system
- Drip Distribution system

120 mpi and greater

Non-Soil Based Treatment Systems. Section F

At-Grade and Mound Systems

A sewage treatment At-grade or mound is a bed elevated to provide 3-feet of separation distance from a confining layer, such as, clay, high water conditions, or bedrock. The mound must be carefully constructed to provide adequate sewage treatment. **Mound failures are usually traced to improper design and construction practices.**

Sewage Treatment Mounds for Problem Locations

Suitable soil provides excellent treatment of sewage tank effluent, and the natural topsoil should be utilized for treatment wherever possible. However, some locations do not have soils or soil profiles suitable for treatment of sewage using lateral systems. For instance, some soils do not have the ability to accept effluent, which is necessary for the proper operation of the soil treatment system. In other soils, there are seasonal water tables at depths closer than three feet to the ground surface, such that adequate vertical separation of the soil treatment unit is not possible under "natural" conditions, or soils with a hardpan layer that restricts downward movement of the water, or with fractured or permeable bedrock, all present problems for adequate treatment and/or acceptance of septic tank effluent.

Mounds Treat Sewage Effectively

Properly designed and constructed sewage treatment mounds are an effective method of onsite sewage treatment. Mounds are basically a sandfilter system that is constructed on top of the ground.

Sufficient numbers of mounds have been installed in Minnesota, Wisconsin and elsewhere to prove that the mound treatment system is a standard technology. There are more than 8,000 single-family mounds successfully treating sewage in Minnesota, and 30,000 in Wisconsin.

Important factors in the design and successful operation of a sewage treatment mound are:

- location,
- size and shape,
- soil surface preparation,
- construction procedures,
- distribution of effluent,
- dosing quantity, and

- quality of clean sand fill.

A vertical separation of at least three feet is required between the bottom of the rock bed and any restricting layer in order to maintain aerobic conditions and treat the wastewater. When aerobic conditions exist in the clean sand, the long-term acceptance rate of the sand is typically 0.8 to 1 gallons per day per square foot. If the depth to the restricting layer is inadequate or the rock bed is too wide, anaerobic conditions may exist and cause a much slower acceptance rate. The possibility of anaerobic conditions occurring in the clean sand, and subsequent hydraulic failure, is a major design consideration when mounds wider than 15 feet –18 are used.

See Figure D-10 for a diagram of a mound. Mound construction begins with the layer of clean sand, which must be at least one-foot thick. The top of the clean sand layer must be level. Distribution pipes are placed in the clean rock. A sandy loam cap, six inches thick at the side and 12 inches thick at the center, is placed over the rock layer.

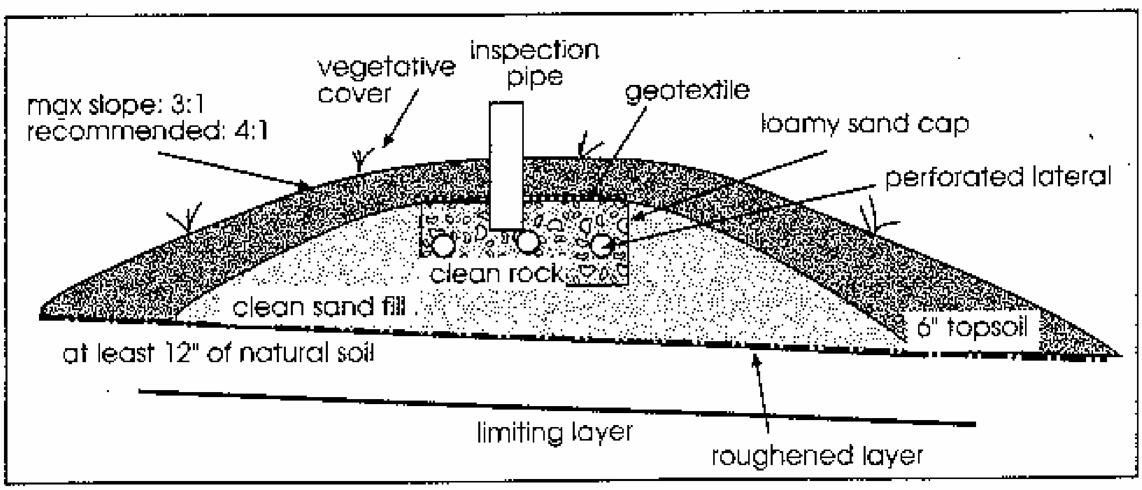


Figure D-10

Complexities of Mound Design and At-Grade Systems

The following design information is for mounds that will serve single-family residences, or daily sewage flow rates of no more than 1,200 gallons. It is not necessarily appropriate for designing systems to treat larger flows, because proper hydraulic operation of a mound depends on lateral as well as vertical seepage.

The following are design guides for Mounds and At-Grade Systems. Before an above grade system is designed, a site evaluation must be performed by a qualified evaluator. In addition, a trained designer must design the system.

The design criteria of this section cannot be simply multiplied by a scale factor to design mounds that will treat larger flows. The hydraulics of lateral and vertical movement, in the clean sand layer and in the soil under the elevated rock bed, must be carefully analyzed to ascertain that anaerobic conditions will not exist. Thus, both lateral and horizontal permeability of the underlying soil layers must be utilized to estimate the height of the saturated zone.

Where heavy clay soils with slow permeability and high seasonal saturated conditions exist over an area, it is far better to utilize mounds for one or two single-family residences than to collect the effluent from many residences and attempt to treat it and dispose of it at a single location. Flow hydraulics in clay soils will require either large depths of fill, or under-drainage, or both, to properly treat sewage. Without fill or underdrainage, anaerobic conditions under the rock layer are likely to develop.

As an example, a mound designed to treat a 3 bed room home (450 gallons per day) may function well under clay soil conditions, while a single mound serving 8 bedrooms (1200 gpd) may fail hydraulically if constructed according to the same vertical separation specifications.

Basis for Design

The design of at-grade and mound systems is based on sewage flow, as estimated for other systems, soil flow patterns as dictated by the **linear loading rate,** and the general geometry of a system built above ground.

Linear loading rate (LLR) refers to potential horizontal and vertical flow patterns in the soil. These characteristics are based on soil texture, soil structure, and any limiting layers existing in the soil. The range of the LLR is from 2 to 10 gallons per foot. The 2-gallon per foot minimum allows almost entirely horizontal flow of effluent. This minimum should be used for a system limited by impermeable bedrock or very heavy clay soils, or in any situation where horizontal movement of contaminants is a concern.
The 10 gallon per foot loading rate (the maximum) would be used when water moves down through the soil much faster than it moves sideways, as in a sandy soil profile. Design values should be somewhere between these two. For a “typical” soil horizon made up of a variety of soil textures, a linear loading rate of 3-4 gallons per foot should be used.

LINEAR LOADING RATES FOR ON-SITE SYSTEMS

By
James C. Converse
August, 1998

In sizing on-site systems, the emphasis has been placed on sizing of the bottom area in either gpd/ft^2 or in ft^2/bedroom using either a bed or trench design. This approach has worked reasonably well for in-ground trenches and beds where the limiting condition has been at least 3 ft and the soil has been relatively permeable. However, with the introduction of mounds and at-grades, the site has become more restrictive due to smaller separation distances between the ground surface and limiting condition and more slowly permeable soils, especially on sites limited to the mound. To overcome deficiencies associated with the soil loading rate, the linear loading rate concept was introduced in the 1980s.

> *The linear loading rate is defined as the amount of wastewater applied daily along the landscape contour. It is expressed in gallons per day per linear foot along the contour.*

The linear loading rate concept is a rather simple concept but one that can be hard to understand and interpret on a site by site basis. Where soil loading rates are based on soil texture, structure and consistence, linear loading rates are not as easily assigned for a given soil texture, structure and consistence as other factors such a distance from the ground surface to seasonal saturation or restrictive layers need to be considered. In essence linear loading rates have been used indirectly in the design of mound systems. Mounds in the State are not all the same length for a given daily design flow but vary in length depending on soil/site conditions. For example, in some parts of the state, the mound absorption area may be 100 ft long while in other parts of the state they may be 60 ft long. For a 3 bedroom home, the linear loading rate for the 100 ft long absorption area is 4.5 gpd/lf while for the 60 ft long absorption area it is 6.7 gpd/lf.

Assigning a linear loading rate is as much of an art as it is a science. In most situations, it has been based on judgement and experience. Thus, the following will serve as a guide for assigning linear loading rates and thus dictating the system length along the contour. Linear loading rates are not affected by effluent quality as is soil loading rates. The linear loading rate relates to getting the effluent away from the soil absorption unit and the soil loading rate is more related to clogging mat/soil interaction. Applying highly pretreated effluent (sand filter and aerobic unit effluent) will allow downsizing of the absorption area (increase soil loading rate in gpd/ft^2) but it will not affect the linear loading rate. Thus the length of the soil dispersal unit receiving highly pretreated effluent will be similar to a mound receiving septic tank effluent on similar soil profiles.

Figure 1 illustrates the concept. The left diagram represents the soil treatment /dispersal bottom area (LxW) for septic tank effluent and the arrows on the bottom represent the linear loading rates. The middle and right diagrams represent the soil treatment/dispersal bottom area assuming the site will accept 50%

downsizing (LXW)/2, resulting in soil loading rate (gpd/ft^2) twice that of the left diagram. The bottom area of the middle and right diagrams are equal but the linear loading rate on the right one is twice that for the middle one because it is half as long. The linear loading rate of the right one is 2 times the liner loading rate of the left diagram but the middle diagram has the same linear loading rate as the left diagram. The site might not be able to handle the linear loading rate assigned to the right diagram (2 times) and thus the design for the site may be inappropriate.

Figure 2 in the Wisconsin Mound Manual and the Wisconsin At-grade Manual provides excellent graphics of water movement away from mounds and at-grade units. It is similar for other soil dispersal units such as in-ground beds/trenches with restrictive layers (seasonal saturation, slowly permeable soils), especially if separation distance is only one to two feet which may be the case for highly pretreated effluent. The discussion presented in the manuals gives the designer a better understanding of what linear loading rate to assign to a given soil profile.

If the design is for a replacement system, the existing system length may be a good indicator of the linear loading rate for the site if the system failed because of longevity (clogging). If it surfaces only during high seasonal saturation then failure may be due to the fact that the effluent can not move away from the distribution cell fast enough. Thus, the linear loading rate may need to be reduced for the new system, resulting in a longer system. However, the seasonal saturation may intrude into the system because seasonal saturation may be close to, at or above the bottom of the system. On some sites, where limiting conditions may not allow for the most appropriate linear loading rate, the designer must decide the degree of risk he/she is willing to take that 1) effluent will leak out the mound toe or 2) effluent will pond in shallow in-ground trench during stress periods.

The following examples will provide some guidelines in assigning linear loading rates.

Site 1.

Soil/Site Conditions

0-6" Silt loam with moderate medium subangular blocky structure and friable consistence.

6-14" Clay loam with weak subangular blocky structure and friable consistence

14-24" Clay loam with massive structure and very firm consistence.

Seasonal saturation at 6" but may be higher as it is difficult to determine redoximorphic features in the top soil. Slope of 5%.

3

Summary

Highly pretreated effluent would enter the silt loam surface horizon relatively easy because of the structure and consistence. During the drier seasons, the effluent would move vertically downward to the clay loam horizon where it would be held up somewhat because of the texture and weaker structure. Since this profile has a slower permeability some of it would move horizontally and as it moves horizontally, gravity and capillary action would pull it downward. As it reaches the next lower horizon, the vertical flow is slowed up because of the massive structure and very firm – consistence. Depending on the degree of massiveness, some will move vertically while the majority will move horizontally. During wet seasons (saturation at 6" or so), the situation is aggravated further because there is no vertical movement. A linear loading rate of 3 gpd/lin.foot is suggested for this site. Also, during the wet season, there is a good possibility of a spongy toe and toe leakage out of the modified mound especially if the surface horizon consists of slowly permeable soils such as clay loams. For a system serving a 3 bedroom home (450 gpd), the distribution cell (aggregate) length would be 150 ft along the contour.

Site 2

Soil/Site Conditions

0-8" Silt loam with moderate medium subangular blocky structure and friable consistence.
8-17" Silt loam with weak, medium subangular blocky structure and firm consistence.
17-40" Clay loam with strong, medium angular blocky structure with firm consistence.
40-60" Clay loam with moderate, fin angular blocky structure with firm consistence.

Seasonal saturation at 17" and site slope of 8%.

Summary

Highly pretreated effluent would enter the silt loam surface horizon relatively easy because of the structure and consistence. As it approached the next horizon, it would be slowed up slightly because of the weak structure and firm consistence with some horizontal movement but mostly vertical movement. As it approaches the third horizon, it would be slowed some because of texture change but still have significant vertical flow. During the wet season there would be about 17" of vertical soil for the effluent to move horizontally away from the system. A linear loading rate of 5 gpd/lf may be appropriate for this site if the separation distance is a t least 17". For a shallow in-ground trench with the bottom at 5" below the surface a similar linear loading rate may be appropriate but the system will be somewhat stressed which may result in possible ponding occurring in the distribution cell (aggregate, chamber).

Thus the designer must be cognizant how the effluent moves away from the soil dispersal unit especially on the more restrictive sites which, for the most part, is the case when highly pretreated effluent is applied.

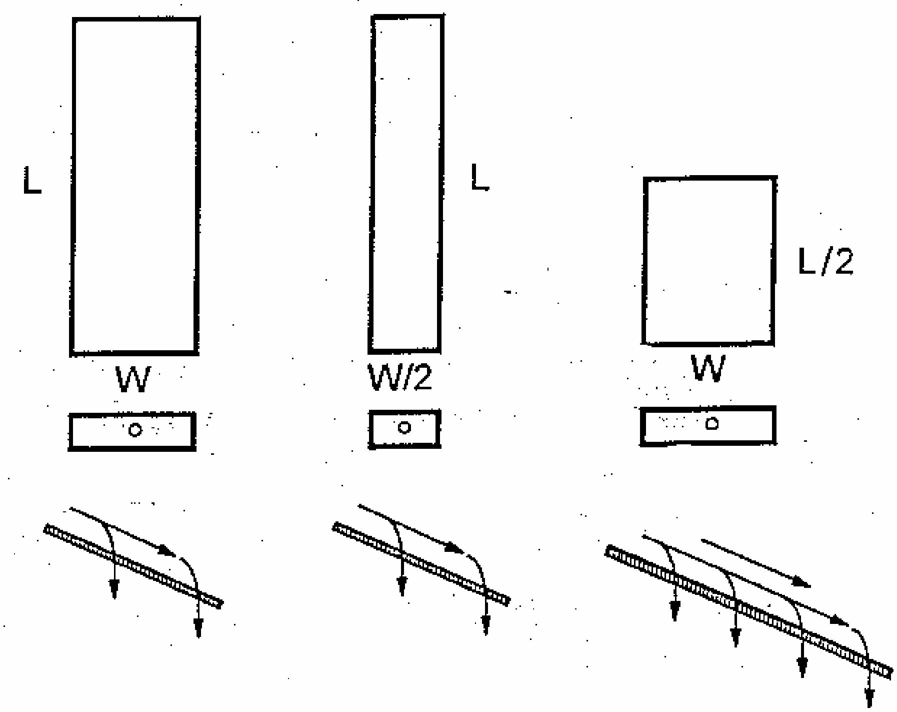


Fig. 1. These three diagrams illustrate how downsizing configuration affects linear loading rates. The left diagram represents the full size system. The middle one represents a half size system (bottom area) resulting in twice the soil loading rate and the same linear loading rate. The right one also represents a half size system (bottom area) resulting in twice the soil loading rate and but also twice the linear loading rate.

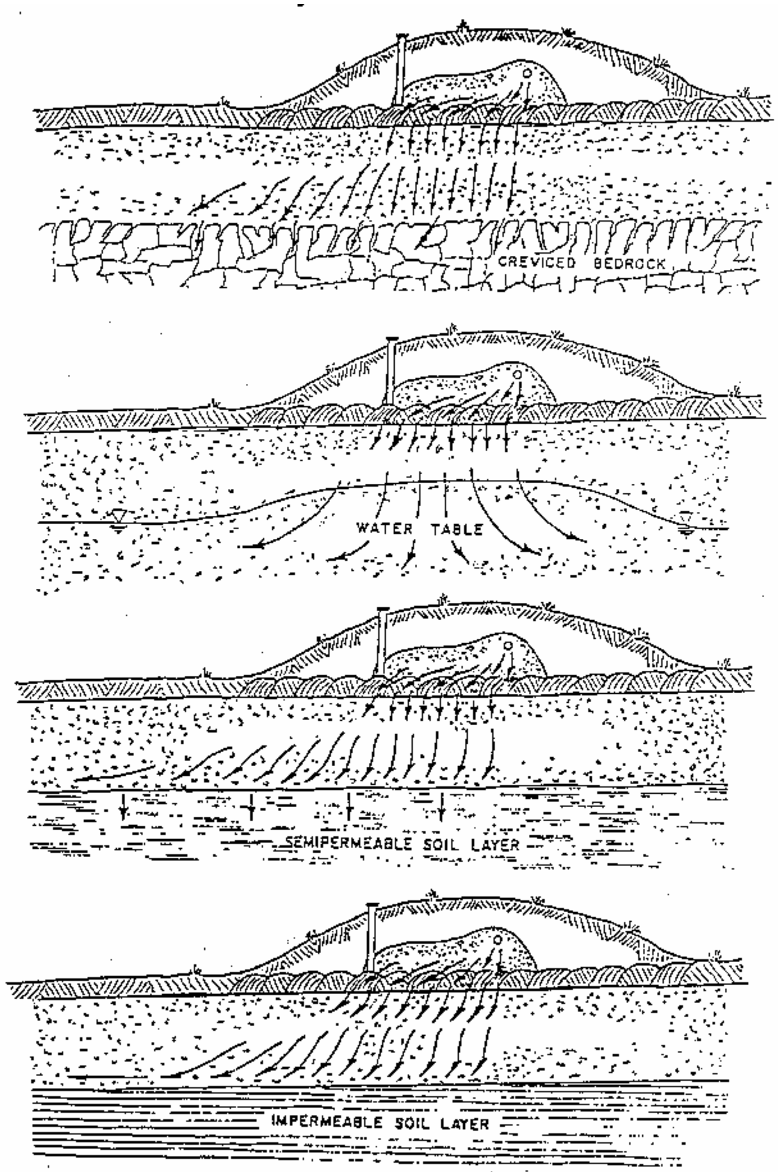


Fig. 2. This schematic represents flow away from a soil treatment unit under various soil/site conditions illustrating at-grades but suitable for mounds and other soil systems. The upper one represents permeable soil over creviced bedrock with mainly vertical flow. The other three represents more restrictive conditions resulting in lower linear loading rates.

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THE OHIO STATE UNIVERSITY

Bulletin Extension

Mound Systems for On-site Wastewater Treatment

Siting, Design and Construction in Ohio

Bulletin 813-90

Siting

For any soil absorption system, the Ohio Household Sewage Disposal Rules require a minimum separation distance of 4 feet between the bottom of a wastewater distribution system and a limiting condition. This depth is considered necessary to treat wastewater to acceptable standards. Sufficient depth of suitable unsaturated soil exists in some areas of the state, allowing installation of a conventional soil absorption system. If the proposed site does not provide this depth naturally, suitable sand fill in a mound may make up the difference. Figure 1b is an illustration of site conditions where conventional soil absorption systems and mound systems could be used.

Before a mound system is designed, a site evaluation must be performed by a qualified soil scientist or sanitarian (soil evaluator). The most important information from a site evaluation will be an identification of limiting conditions at the site and a basic understanding of how wastewater will move away from the system.

Figure 3 shows a schematic of effluent movement within and away from mound systems for various soil profiles. Depending on limiting conditions in the profile, effluent moves away from the site vertically, horizontally, or a combination of both. Common limiting conditions are impermeable or slowly permeable subsoil layers, shallow depth to bedrock and seasonal high water table.

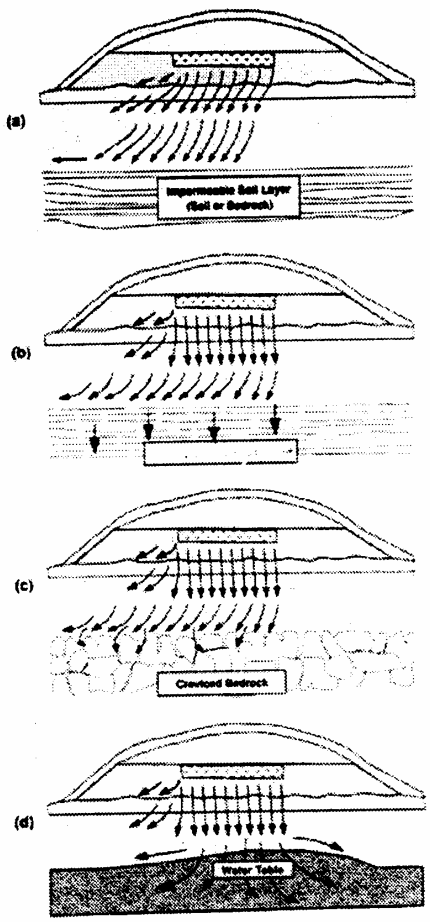
Figure 3a shows an impermeable layer beneath the mound. In this case effluent moves freely into the topsoil, but then moves horizontally away from the system upon reaching the impermeable layer.

In figure 3b effluent moves downward through the mound and into the surface horizon. Upon reaching a semipermeable soil layer, a portion of the effluent is diverted horizontally away while some effluent continues to infiltrate vertically.

Figure 3c shows effluent moving primarily downward towards and then into creviced or porous bedrock. Figure 3d illustrates effluent moving vertically to a mounded high water table, and then horizontally away within the water table.

Mound systems may be appropriate for all of these profiles, however, the situations illustrated in Figures 3a and 3d represent more restrictive sitings than those in Figures 3b and 3c. Whenever a significant portion of effluent movement away from the mound is horizontal, as in Figures 3a and 3d, the mound should be designed longer and narrower. This reduces the effluent loading rate per linear foot of the system and decreases chances of surface seepage.

Linear Loading Rate



(a) 3 - 4 gpd/lf
Impermeable Soil Layer (Soil or Bedrock)

(b) 5 - 6 gpd/lf
Semipermeable Soil Layer

(c) 8 - 10 gpd/lf
Creviced Bedrock

(d) 3 - 4 gpd/lf
Water Table

The determination of mound dimensions will depend upon an understanding of effluent movement away from the mound. This includes both the direction of effluent movement and the rate of movement. Note that the configuration of any soil absorption system is based on these concepts. The information needed is obtained during the site evaluation. The soil evaluator should work with the designer and installers for best performance of the system.

Soil Sizing Factor for Clean Sand

The soil-sizing factor for the clean sand layer of the mound is 1 gallon per square foot of wastewater per day. Clean sand is required! Clean sand is defined in Figure D-11. Chapter 69 states that IDOT concrete sand is acceptable for sand filters and may be used for Mounds.

Figure D-11: Clean Sand		
sieve number	sieve size (mm)	percent passing
4	4.75	95 to 100
8	2.0	80 to 100
10	0.85	0 to 100
40	0.425	0 to 100
60	0.212	0 to 40
200	0.075	0 to 5

Clean sand can also easily be determined in the field by using the jar test (see Figure D-12). Place exactly two inches of sand in the bottom of a quart jar and then fill the jar three-fourths full of water. Cover the jar and shake the contents vigorously.

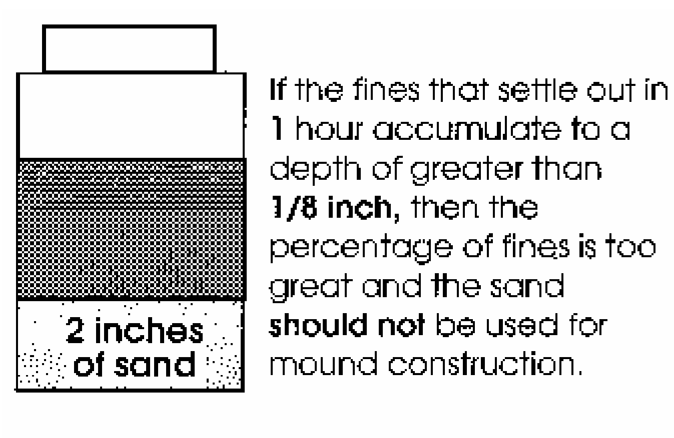


Figure D-12

Allow the jar to stand for about an hour and observe whether there is a layer of silt or clay on top of the sand. If the layer of these fine particles is more than 1/8 inch thick, the sand is probably not suitable for use in mound construction, because too many fine particles tend to cause the soil to compact during the construction process. Also, the long-term acceptance rate of this soil will be slower than the long-term acceptance rate of clean sand, which is used for sizing the rock layers.

AT-GRADE SYSTEMS FOR ON-SITE WASTEWATER TREATMENT AND DISPERSAL

James C. Converse[1]
January 1999

The Wisconsin at-grade soil absorption system was developed in the early 1980s for sites that were not suitable for in-ground trenches/bed and exceeded requirements for mounds. The "Wisconsin At-grade Soil Absorption System Siting, Design and Construction Manual, known as the at-grade manual, serves as the basic siting, design and construction manual for at-grade units (Converse et al. 1990). It has been accepted and used in a number of states. Due to its site limitations it is not as versatile as the mound or in-ground system. Fig. 1 shows a schematic of the at-grade unit. Care must be taken in making modifications to the at-grade unit so a to minimize failures. All three factors, siting, design and construction principles must be closely adhered to as to minimize the risk of system failure. The on-site professional, i.e., the soil evaluator, designer, installer and inspector must understand the principles of operation of the at-grade system before an attempt is made to site, design and install it. Operational and management must also be an integral part of the equation.

The purpose of this paper is to provide information on the siting design and construction concepts of the at-grade. **The reader should obtain a copy of the 1990 At-Grade Manual[2] for a complete discussion on siting, design and construction.**

Figure 1 shows the components of the at-grade system. The system consists of a septic tank and the at-grade unit. A pump chamber is included if pressure dosing is required. If gravity flow is used, a distribution box should be placed in the up slope portion of the unit to provide at least 3 drop points along the length of the unit.

Fig. 2 shows the landscape location of the at-grade unit in relation in-ground trenches/beds and mound systems.

PRETREATEMENT UNIT

The septic tank serves as the pretreatment unit for the at-grade unit. Converse (1999) discusses several options for septic tank/pump chamber combinations. If gravity flow is the option, then a single compartment or double compartment septic tank with an effluent filter is sufficient. If

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[2] The Wisconsin at-grade manual and related publications can be obtained from SSWMP, University of Wisconsin-Madison, 1525 Observatory Drive, Room 345. 608-265-6595. A publication list is available upon request at no cost. Three is a small charge to cover copying and mailing. It can also be ordered over the web at hppt://www.wisc.edu/sswmp.

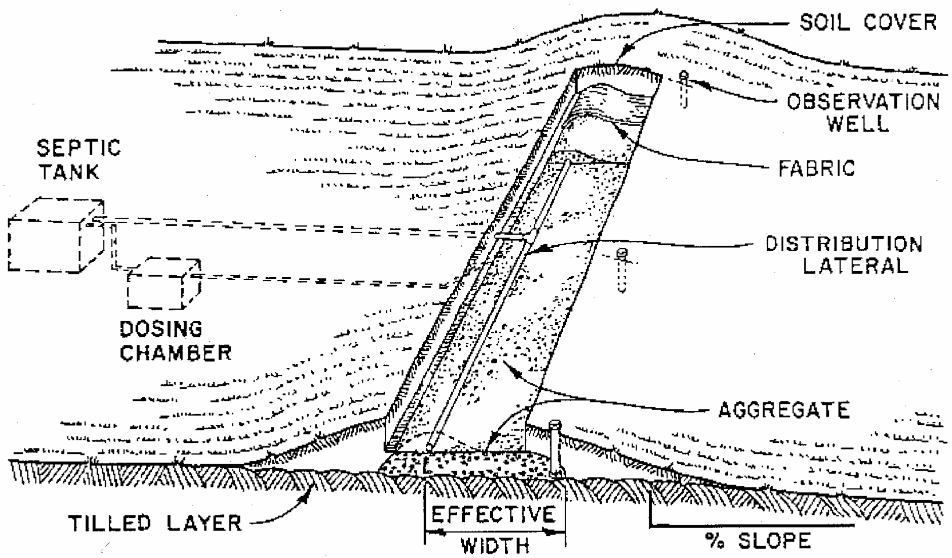

Fig 1. Schematic of the at-grade soil absorption system. Note that both pressure distribution and gravity flow distribution are shown. In actual practice, only one will be installed (Converse et al. 1990).

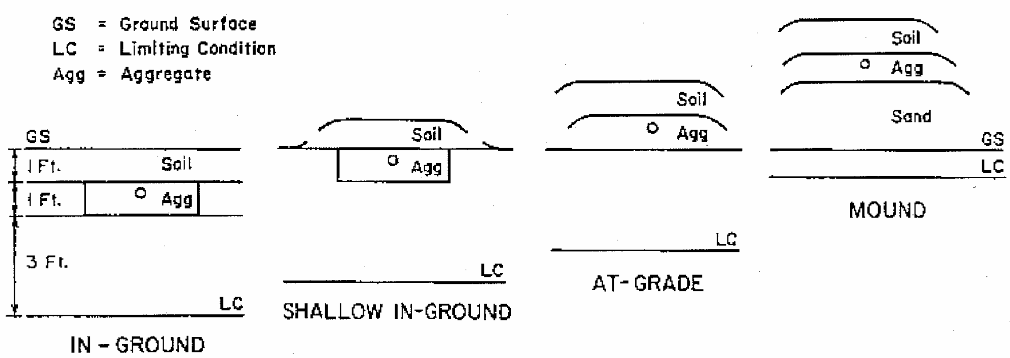

Fig. 2. Cross section of 4 soil absorption units shown in relation to ground surface and limiting conditions.

pressure distribution is the choice, then the following options may be considered.

1. A single compartment septic tank with effluent filter followed by a single compartment pump chamber.

2. A double compartment tank with the first compartment containing the effluent filter serving as the septic tank and the second compartment serving as the pump chamber.

3. A double compartment tank with both compartments serving as a septic tank with an effluent filter at the outlet of the second compartment, followed by a single compartment pump chamber. This may be the desired alternative as an "aerated baffle", known as the Nibbler Jr. (NCS, 1998) could be placed in the second compartment to reduce the organic matter if the at-grade unit ever fails due to breakout of effluent. The conversion would be minimal.

4. A single compartment tank with a pump vault within the septic tank. The effluent filter is incorporated in the pump vault that suspends from the outlet of the septic tank. An alternative is a double compartment tank with a hole in the center of the dividing wall to connect the two compartments together in the clear zone and the pump vault in the second compartment.

Demand dosing versus timed dosing for pressure distribution units.

Recent research on single pass sand filters shows that short frequent doses to the sand filter improves effluent quality (Darby et al., 1996). Short frequent doses require time dosing instead of demand dosing. Most at-grades are demand dosed where a large quantity of effluent is discharged into the mound. This large quantity of effluent moves through the sand rapidly (assuming no ponded condition), allowing insufficient time for the biota to totally treat the effluent. This forces fecals and pathogens further into the soil profile. Short frequent doses allows the effluent to be retained in the sand/soil for longer periods. Converse et al. (1991) showed some fecals found deep in the soil profile beneath at-grades. It may have been due to large infrequent doses. **Designers must consider using smaller doses when using demand dosing and they may want to consider timed dosing in distributing the effluent to the at-grade.** Timed dosing requires that surge capacity be incorporated into the septic tank and /or pump chamber to store the peak flows until it is dosed into the mound. Timed dosing also required control panels which have become very user friendly. Converse (1999) discusses the various options in more detail including pump vaults, effluent filters and time/demand dosing.

SITING CRITERIA

A designer must have a basic understanding of wastewater movement into and through the soil especially on more difficult sites. Typically the sites are not as difficult for at-grades as they are for mounds as there is a greater distance from the ground surface to the limiting condition such as bedrock or saturation. If the code separation distance is less than 3 ft, then the difficulty becomes greater. However, there may be other characteristics such as soil banding that may be a factor in selecting at-grades over in-ground trench/bed units. Fig. 3 shows a schematic of effluent movement away from the at-grade under various soil profiles. Depending on the type of profile, the effluent moves away from the unit vertically, horizontally or a combination of both. These concepts are true for all on-site systems. Fig. 3a, (top figure) shows the movement primarily vertical where the soil is very permeable or crevice bedrock is present that allows for vertical movement. Fig. 3b shows a high seasonal or permanent water table. When the effluent reaches the saturated condition, it is forced horizontally as all the soil pores are full of water. Fig. 3c shows a semi-permeable condition beneath the surface. As the effluent reaches the semi-permeable area, it forces some of the effluent to move horizontally with some of it moving vertically until it reaches a point where it all moves vertically. Fig. 3d shows an impermeable layer beneath the surface. As the effluent reaches the impermeable area, it forces the effluent to move horizontally. Undoubtably, there will be some leaks in the restrictive layer with effluent moving downward. These conditions affect how the at-grade is configured. The designer must predict the direction and rate of movement or the design may be flawed resulting in treated effluent breaking out on the ground surface. The prediction is based on soil and site information obtained during site evaluation and experience.

The sizing and configuration of all soil absorption units, including at-grades, is based on how the effluent moves away from the unit and the rate at which it moves away.

Soil and Site Limitations:

Table 1 gives the soil and site criteria for Wisconsin at-grade systems used in Wisconsin. These distances may vary depending on code requirements in other areas. The separation distance for all soil based units receiving septic tank effluent is 3 ft. If the requirement were 4 ft than 4 ft would be used in Table 1.

Soil Loading Rates:

The design soil loading rate is based on the soil horizon that is in contact with the aggregate which is the surface horizon for the at-grade system (Table 2). Evaluation of the soil profile to a depth of 3 ft must be done. If a restrictive horizon is encountered, the tendency is to use the loading rate for the more restrictive horizon which results in an enlarged aggregate area. At the same time the linear loading rate must be appropriately selected otherwise toe leakage may occur. **The configuration of the at-grade must fit the soil profile with the soil loading rate and the linear loading rate matching the soil profile.**

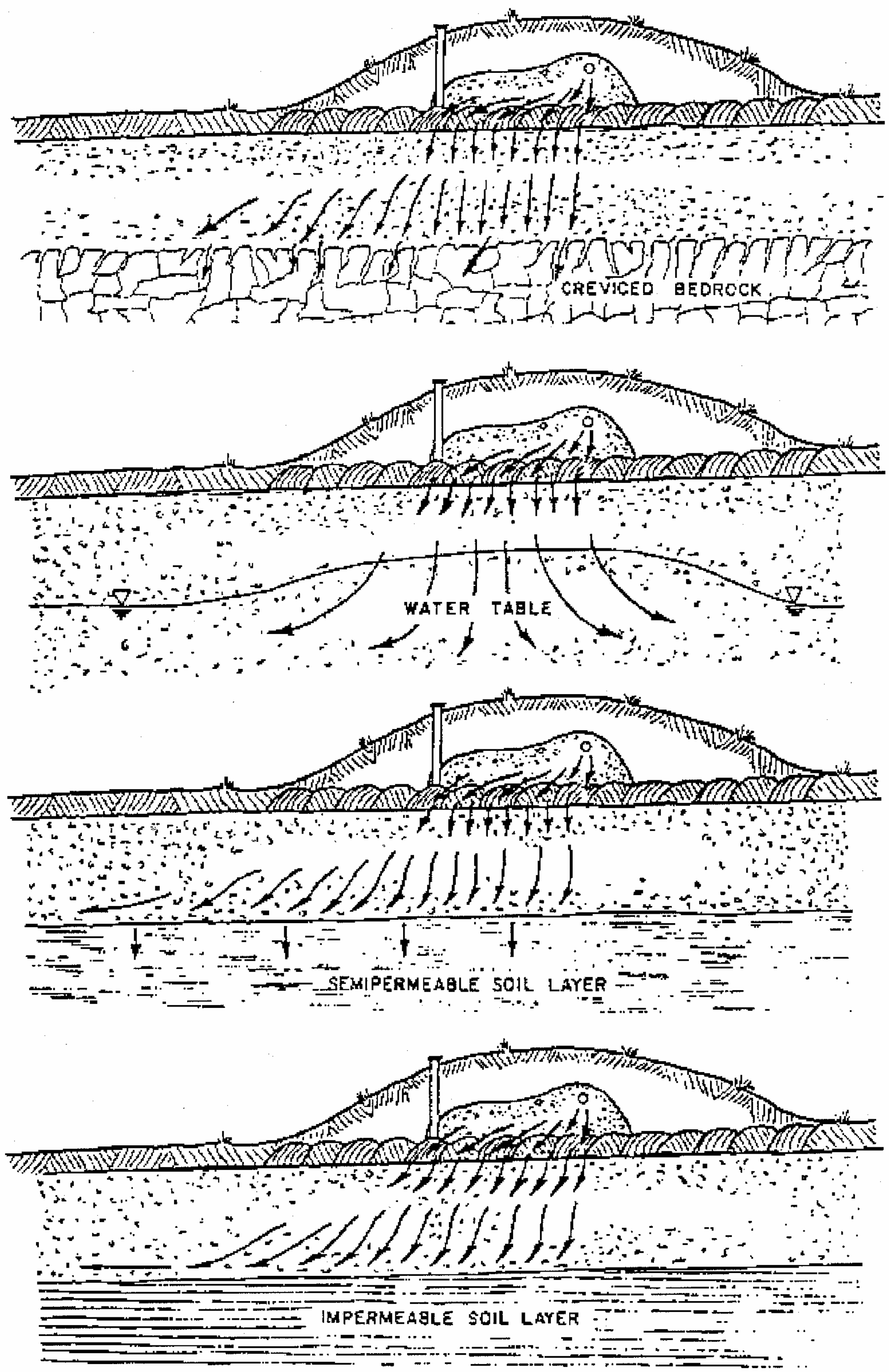

Fig. 3. Effluent movement away from the at-grade units under four different soil profile conditions (Converse et al. 1990).

Table 1. Soil and site criteria for the Wisconsin at-grade system used in Wisconsin (Converse et al. 1990).

Parameter	Limits
Depth from surface to high water[a]	3 ft
Slopes from surface to bedrock	3 ft
Surface slope[b]	<25%
Soil permeability	c
Flood Plain	No

[a] Seasonal saturation is estimated by mottles.
[b] Slopes limited due to construction. Some systems have been placed on steeper slopes. Slopes > 15% must incorporate pressure distribution.
[c] The soil permeability is estimated using soil texture, structure and consistence. Soil permeability limits for at-grades will be similar to in-ground trenches/beds.

DESIGN PRINCIPLES

System Configuration:

The system configuration must meet the soil site criteria and fit on the site. As with all soil absorption units, they should be long and narrow (Tyler and Converse, 1985; Converse and Tyler, 1986). Prior to the design, the soil evaluator/designer must use the soil profile description to 1) estimate the effluent acceptance rate of the soil and 2) determine the flow path of the effluent as it moves through the soil profile. If there is a restrict layer such as soil banding, hard pan, platy structure or high water table, the flow may be primarily horizontal and thus the design long and narrow. If there is no restrictive layer, then the flow will be vertical and the effective width of the system may be greater. It is difficult to determine the exact effective width of the system. A system that is too wide may leak at the down slope toe or either toe on level sites. Other factors such as gas transfer and exchange beneath the absorption area are also affected by the width of the system (Tyler et al. 1986). If there isn't sufficient length along the contour, but there is sufficient length along the slope, then it may be possible to stack them up the slope sufficiently apart so the up slope unit does not impact the down slope unit (Converse et al. 1990). Fig 4 shows a cross section and plan view of an at-grade unit on a sloping site.

Effect Absorption Area:

The effective absorption area is that which is available to accept effluent (Fig. 4). The effective length is the actual length of the aggregate along the contour. The effective width on sloping sites is the width from the distribution pipe to the toe of the aggregate and on level sites it is the

Table 2. Estimated wastewater design soil loading rates for the surface horizon based on soil morphological conditions for Wisconsin at-grade systems (Converse et al., 1990).

Soil condition in contact with the aggregate (Instructions: Read questions in sequence. When the conditions of your soil match the question, use that loading rate and do not go further).	If yes the Loading Rate in gpd/ft^2 Is:
A. Is the horizon gravelly coarse sand or coarser?	0.0
B. Is consistence stronger than firm or hard, or any cemented class?	0.0
C. Is texture sandy clay, clay or silty clay of high clay content and structure massive or weak, or silt loam and structure massive?	0.0
D. Is texture sandy clay loam, clay loam or silty clay loam and structure massive?	0.0
E. Is texture sandy clay, clay or silty clay of low clay content and structure moderate or strong?	0.2
F. Is texture sandy clay loam, clay loam or silty clay loam and structure weak?	0.2
G. Is texture sandy clay loam, clay loam or silty clay loam and structure weak?	0.4
H. Is texture sandy loam, loam, or silt loam and structure weak?	0.4
I. Is texture sandy loam, loam or silt loam, and structure moderate or strong?	0.6
J. Is texture fine sand, very fine sand, loamy fine sand, or loamy very fine sand?	0.6
K. Is texture coarse sand with single grain structure?	0.8

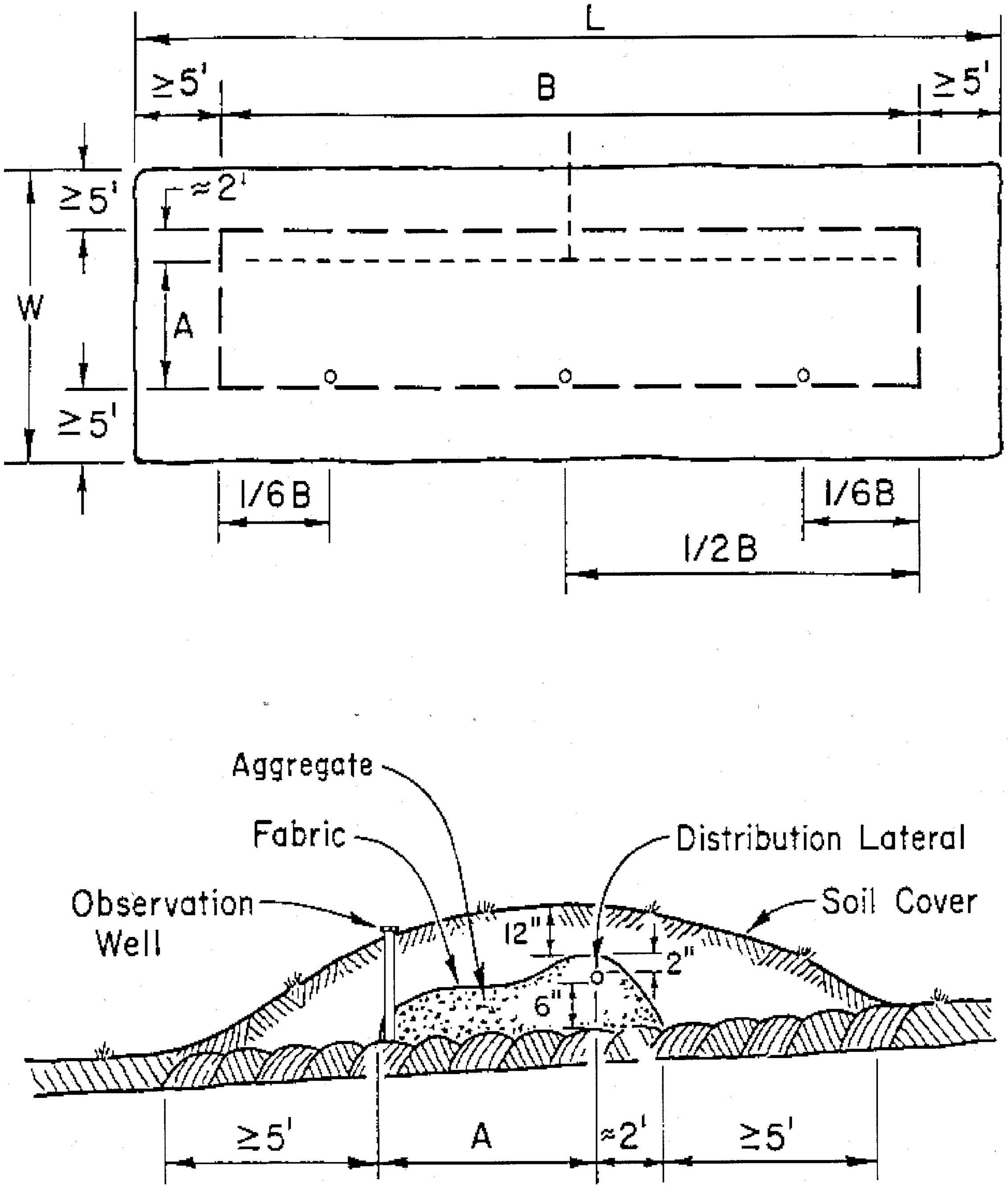

Fig. 4. Cross section and plan view of an at-grade unit on a sloping site (Converse et al, 1990)

width of the aggregate area. Table 2 is used to determine the area of the effective aggregate area and the linear loading rate determines the length and width of the effective area.

Linear Loading Rate:

The linear loading rate is defined as the amount of effluent (gallons) applied per day per linear foot of the system along the natural contour (gpd/lf). The design linear loading rate is a function of effluent movement rate away from the system and the direction of movement away from the system (horizontal, vertical or combination, Fig. 3). If the movement is primarily vertical (Fig. 3a), then the linear loading rate is not critical. If the movement is primarily horizontal (Fig. 3d), the linear loading rate is extremely important. Figure 5 illustrates the effect of linear loading rate on the configuration selected. Other factors such as gas transfer beneath the absorption area suggest that the absorption area width be relatively small (Tyler et al., 1986).

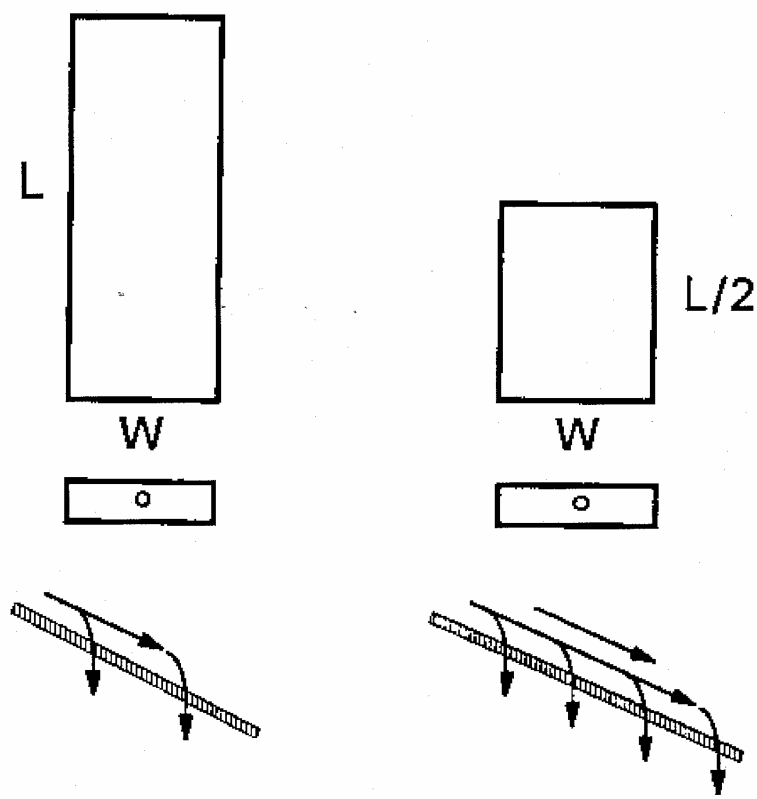

Fig. 5. The effect of linear loading rate based on system configuration on a sloping site. The sand or soil loading rates (gpd/ft^2) are the same but the linear loading rate for the right figure is twice that of the left figure. The soil may not be able to move the effluent away from the system fast enough resulting in back up and breakout at the mound toe.

It is somewhat difficult to estimate the linear loading rate for a variety of soil and flow conditions but based on the authors' experience "good estimates" can be given. If the flow is primarily vertical (Fig. 3a), then the linear loading rate can be high but should be limited to a range of 8-10 gpd/lf otherwise the absorption area is excessively wide, especially if the soil absorption unit is the slower permeable soils such as silt loams. If the flow is primarily horizontal because of a shallow restrictive layer or limiting condition such as seasonal saturation or bedrock (Fig. 3d) then the linear loading rate should be approximately 3 gpd/lf, resulting in long and narrow systems. Converse (1998) gives a more detailed explanation and provides two examples of estimating linear loading rate.

Total Length and Width:

It is necessary to add about 5 ft to each end and sides to tie the system to the existing soil surface with the soil cover. These widths can be greater than this. Thus, the total length is sum of the aggregate length plus 10 ft and the width is the effective width, the aggregate up slope of the distribution lateral plus 10 ft (Fig.4).

Distribution Network:

The at-grade unit can be designed for either gravity or pressure distribution. Pressure distribution requires a pump tank with added costs but it does spread the effluent along the length of the unit and utilizes the total effective area of the aggregate. **Pressure distribution is the preferred and recommended method of distribution.** Fig. 6 shows the typical distribution pattern for pressure and gravity utilizing a distribution box up slope. Gravity distribution should be used in conjunction with a distribution box so the flow can be directed to at least 3 drop points along the length of the unit. Converse et al. (1990) show distribution patterns for level sites and provides a detailed discussion relative to pressure and gravity distribution.

Observation Tubes:

Observation tubes, extending from the aggregate/soil interface to or above final grade, are placed in the absorption area to provide easy access for observing ponding in the aggregate. On sloping sites the tubes are placed at the 1/4 and 3/4 points along the contour at the toe of the aggregate. The tube must be perforated along the bottom 6" of the side wall and secured using a toilet flange, tee or reinforcing rods (Converse et al., 1990).

Cover:

A geotextile synthetic fabric is placed on the aggregate. Approximately 8 – 12" of soil cover is placed over the aggregate extending at least 5 ft beyond the edge of the aggregate. The cover should support vegetation. Erosion protection must be implemented before a vegetative cover is established.

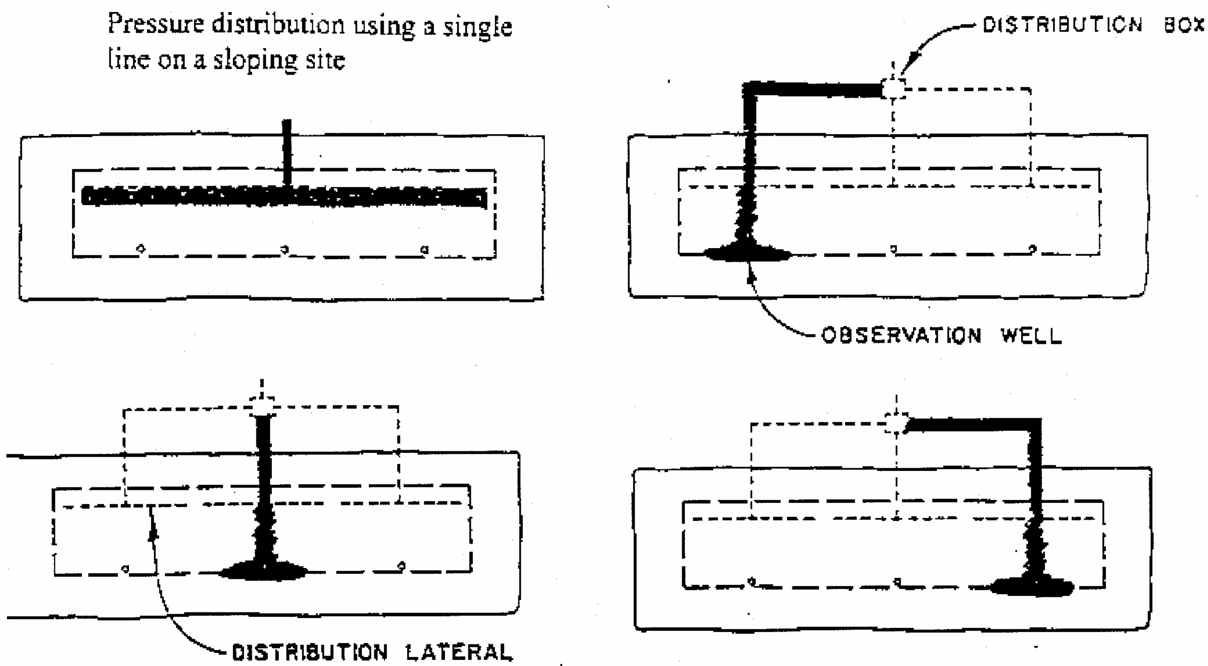

Fig. 6. Typical distribution patterns for pressure distribution (top left) and gravity flow with a distribution box with 3 drop points on sloping sites. Distribution box should sit in the upslope edge of at-grade (Converse et. Al., 1990).

DESIGN EXAMPLE

Design an on-site system based on the following soil profile description (modified from Converse et al., 1990).

Site Criteria

1. Soil profile is- Summary of 3 soil pit evaluations.

   0 – 12" Sil; 10YR 6/4&2/1; moderate, medium, subangular blocky structure; friable consistence.
   12 – 36" Sicl; 5YR 3/1; moderate, fine subangular blocky structure; firm consistence
   36+" Sic; 10YR 5/3; strong, medium, platy to massive structure; very firm consistence; many medium, prominent mottles at 3 ft.

2. Slope is 20%

3. Distance available along the contour is 170 ft and along the slope it is 30 ft.

4. Design is for a 3 bedroom house.

It appears that an at-grade system is suited for this site because the estimated saturation is at 36" the surface horizon is permeable and code setback requirements are assumed to be satisfied.

Step

1. **Determine the design flow rate (DFR).**

   Since this is a 3 bedroom home, use 150 gpd/bedroom.

   DFR = 3 br x 150 gpd/br
   = 450 gpd

2. **Estimate the soil loading rate (SLR) for the site.**

   Use table 2 for selecting the appropriate soil loading rate (SLR) that matches the soil conditions. It is based on the soil horizon that is in contact with the aggregate. Since this is a silt loam with good structure and friable consistence, use a

   SLR = 0.6 gpd/ft^2

3. **Estimate the linear loading rate (LLR) for the site.**

   Evaluate the soil profile to estimate the linear loading rate.

   The silt loam surface (A) horizon (0-12") is relatively permeable because of the texture, structure and consistence. The effluent flow will be vertically down through the aggregate, horizontally along the soil surface and vertically into the soil.

   The silty clay loam (E) horizon (12 – 36") has a moderate structure and firm consistence. Table 2 indicates that it can be loaded at 0.4 gpd/ft^2 which is less than the 0.6 gpd/ft^2 for the upper horizon. The consistence is firm which means the flow will be slightly restricted compared to friable. Thus, as the effluent moves downward through the (A) horizon, it will be slowed up because of the texture, structure and consistence change and be forced to move horizontally as effluent moves vertically.

   The silty clay loam (C) horizon (36+") has a strong medium platy to massive structure with very firm consistence. As the effluent from the (E) horizon approaches this horizon, the vertical flow of the effluent is considerably slowed. Effluent moves more slowly through silty clay. The massive nature of the soil slows up flow and the very firm consistence also slows up the flow. The platy structure directs the flow horizontally. Thus most of the flow will be going in the horizontal direction with some vertical movement. Fig. 3c depicts this site. There is approximately 30 – 36" of suitable soil for the effluent to move horizontally away from this site. Thus a linear loading rate of 5 or 6 would be appropriate for this site.

Linear Loading Rate = 5 gpd/lf.

4. Determine the effective absorption width (A) for the unit.

A = LLR / SLR

= 5 gpd/ft / 0.6 gpd/ft^2
= 8.33 ft

5. Determine the effective absorption length (B) for the unit.

B = DFR / LLR

= 450 gpd / 5 gpd/ft
= 90 ft

6. Determine the configuration of the system that best fits the site.

Once the effective width and length of the absorption area are determined, the designer must determine how it will best fit on the site. In this case there is 170 ft along the contour so this unit can be placed on the contour. A linear loading rate of 4.0 would give an an effective absorption length of 113 ft which would also fit on the site.

7. Determine the overall length (L) and the width (W) of the unit.

Add a minimum of 5 ft of soil on both ends and sides.

L = B + 2 end slopes

= 90 ft + 2(5) = 100 ft

W = A + up slope width of aggregate (C) + soil cover side widths
= 8.33' + 2' (estimated) + 2 x 5'
= 20.3' or 21 ft

To add an additional factor of safety, B could be easily increased since length along the contour is available.

8. **Determine the height of the unit.**

   Use a minimum of 6" of aggregate beneath the distribution pipe, and about 2" above the pipe and 8-12" of soil over the aggregate. Place geotextile fabric over the aggregate. The height will be

   H = 6" + 2" +2" + 10"
   = ~20"

9. **Design a distribution network for the site.**

   A pressure distribution network design includes the distribution piping, dosing chamber and pump. A design example is available through Converse et al. (1990). The following points should be considered. Otis (1981) provides a design procedure.

   - Since the absorption area is relatively narrow and on a slope, a single distribution line along the length is satisfactory. It would be located 8.3 ft up slope of the aggregate toe. Another approach would be to use two lines with center feed with one line located at 4.1 ft up slope and one line located 8.3 ft up slope of the down slope toe. If a single line is used place the orifices about 12" apart since the width is about 8 ft. On the two line network, stagger the orifices with 2 ft spacing.

   - Consider using 3/16" holes instead of ¼" holes with an effluent filter on the line. Data is available for 3/16" hole spacing but not in Converse et al. (1990).

   - Timed dosing to the at-grade which requires surge capacity in the septic tank/pump chamber. However, most at-grades will continue to be demand dosed. In both cases the dose volume should be much less than previously recommended with not more than 5 times the void volume of the laterals. For example if the void volume of the laterals within the distribution network was 7 gallons, the dose volume would be 35 gp dose net. The total dose would be 35 gal. plus the flow back of the force main and manifold.

   - **Provide easy access to flush the laterals such as turn-ups at end of laterals.**

CONSTRUCTION

Proper construction is very important. The following steps should be followed when constructing the at-grade units (Converse et al., 1990). There are variations to this approach but the principles should be followed.

Steps

1. Lay out the system with the length following the contour.

2. Cut the grass, brush and trees just above the ground surface and remove. Do not remove tree stumps. In wooded areas rake off dead vegetation if over an inch thick. Avoid heavy traffic on the site.

3. Check for proper soil moisture prior to construction. For single grain soil, the moisture content is not as critical as for structured soil. The soil is too wet to till if it takes on a wire form when rolled between the hands.

4. Determine where the force main from the pump chamber enters the at-grade unit. It will either be an end feed or an center feed. For long units, center feed is preferred. For center feed the force main can enter from the up slope center or the down slope center. If it be brought in from the down slope side, especially on slowly permeable soils where the effluent flow may be horizontal, it should be brought in perpendicular to the side of the unit with minimal disturbance to the down slope area. All vehicular traffic must be kept in a very narrow corridor. Minimal damage is done if the soil is dry. Oil should be packed around the pipe and anti-seep collars should be installed to minimize effluent and water following the pipe. Entering from the down slope center should be the last choice on sites that are slowly permeable with shallow seasonal saturation. Placement of the pipe can be done after tilling but extreme care must be taken not to disturb the tilled area.

5. Till the area following the contour to a depth of 6 – 8". The tilled area should be at least the total length and width of the system. A mold board plow, chisel plow or chisel teeth mounted on a backhoe bucket are satisfactory for tillage. Chisel teeth mounded on a backhoe is the preferred method and it is easier to till around boulder and trees stumps. It also allows for deeper tilling to break up platy structure. A rototiller may be used, but not recommended, on single grain soils, such as sand. The backhoe bucket has been used but not recommended. It requires flipping the soil and much slower than chisel plowing.

   Avoid traffic on the tilled area especially beneath the aggregate area and down slope. If compaction or ruts occur in the up slope or down slope area during construction, retill the compacted or rutted area. Minimize the subsoil disturbance beneath and down slope of the absorption area.

6. Place observation tubes at 1/6, ½ and 5/6 points along the toe of the aggregate area. The tubes must be placed so that ponded effluent at the down slope edge of the aggregate may be observed in the tubes. Stabilize the tubes.

7. Place the aggregate in the designated area of the tilled area to a 6 in depth. **Work from the up slope side and avoid compaction along the down slope side especially if the effluent moves horizontally away from the unit.**

8. Place the distribution network level along the length of the unit and connect the inlet pipe from the pretreatment unit or dose chamber. Place 2 in. of aggregate on top of the network.

9. Place geotextile synthetic fabric over the aggregate. Extend it only to the edge of the aggregate.

10. Place 8-12" of soil over the fabric and taper it to a distance of at least 5 ft in all directions from the aggregate. Finish grading around the system to divert surface water away. Seed and mulch the exposed areas immediately after construction to control erosion.

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SMALL SCALE WASTE MANAGEMENT PROJECT

Wisconsin At-Grade Soil Absorption System Siting, Design, and Construction Manual

by

James C. Converse, E. Jerry Tyler, James O. Peterson

January 1990

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THE WISCONSIN AT-GRADE SOIL ABSORPTION SYSTEM

SITING, DESIGN, AND CONSTRUCTION MANUAL

BY

James C. Converse E. Jerry Tyler James O. Peterson*

The Wisconsin at-grade soil absorption system accepts septic tank effluent and treats and disposes of it in an environmentally acceptable manner. It serves the same function as in-ground soil absorption trenches and mound systems. Figure 1 shows a schematic of the system, which consists of a septic tank and the soil absorption unit. When pressure distribution is used, a dose chamber is required. The existing soil surface is tilled, observation tubes and the aggregate are placed, the distribution network installed, the fabric covering laid on the aggregate and soil cover placed over the fabric and on the side slopes. The hydraulics and treatment concepts are very similar to the in-ground trench or bed and the mound system.

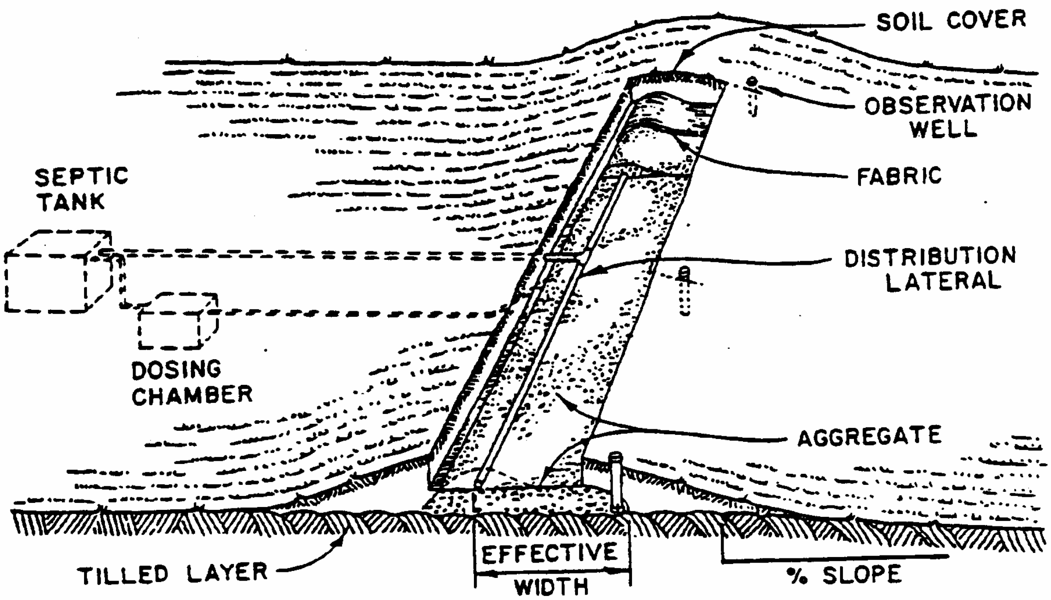

Fig. 1. Schematic of the At-grade Soil Absorption System

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PREFACE

The Wisconsin At-Grade Soil Absorption system is one of several soil absorption systems that can be used to treat and dispose of on-site wastewater through the soil. It is a relatively new system with the first system installed in 1982. Since that time a number of systems have been installed and it appears that this system has a lot of promise on sites that don't meet the criteria for in-ground soil absorption sytems but exceed the criteria for the Wisconsin Mound system.

This publication is an update and succeeds the publication entitled "WISCONSIN AT-GRADE SOIL ABSORPTION SYSTEM MANUAL SITING - DESIGN - CONSTRUCTION" which was dated May, 1989.

The at-grade system will continue to be evaluated. Additional information can be obtained through the SSWMP.

Fig. 2 shows a cross section of 4 soil absorption systems; the in-ground trench or bed, the shallow in-ground trench or bed, the at-grade, and the mound. System selection is based on the soil site criteria established by local or state codes for soil absorption systems.

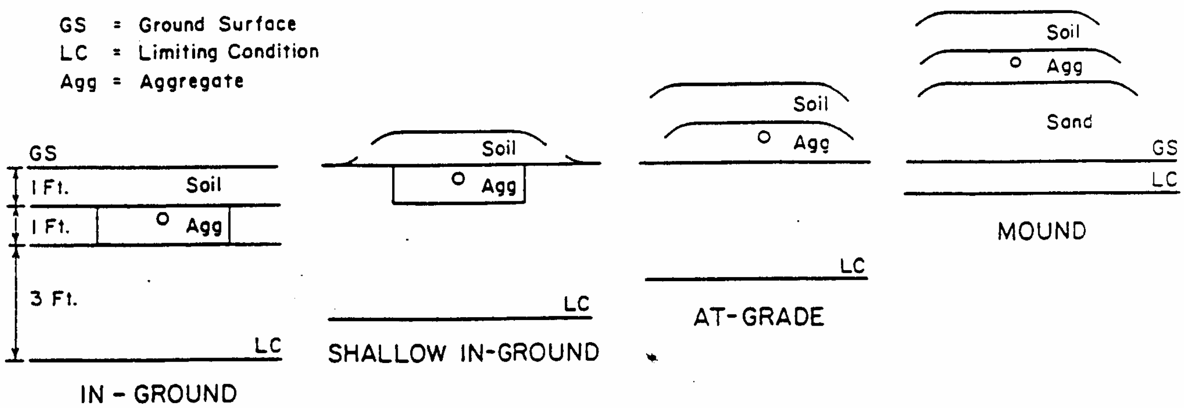


Fig. 2 Cross Section of 4 Soil Absorptions Units in Relation to Ground Surface and Limiting Conditions

The at-grade system has been evaluated in the field with 14 experimental systems which were from 1 to 5 years old and accepting domestic wastes from typical residences. All systems have been performing very well (Converse et al., 1988). As of Jan. 1990, there were over 250 units installed in Wisconsin.

SOIL AND SITE EVALUATION

Selection of the appropriate soil absorption system for a site should consider the following:

1. The landscape and topography for waterways and surface runoff. Avoid placing the system in areas where surface water accumulates or passes downslope.

2. Avoid concave slopes especially if the system will be large. Look for straight slopes, level sites, or convex slopes.

3. Avoid areas that have an excessive number of trees or rocks on the surface. Increase the size of the unit to compensate for the area of the tree stumps and rocks.

4. Evaluate several soil profiles in the area for the following:

   a. Depth to seasonal or permanent high water table for at least the depth dictated by code. It may range from 1 to 4 ft. For Wisconsin it is 3 ft beneath the proposed bottom of the system. For large systems evaluation to greater depths may be necessary.

b. Depth to bedrock for at least the required depth beneath the bottom of proposed system.

c. Texture, color, structure and consistence for at least the required depth beneath the bottom of the proposed system. Evaluate for soil banding, especially in sand textured soils. Evaluate the profile for layers that may restrict effluent flow.

d. Movement of effluent through the soil profile. Will it all move vertically downward? Will it all move horizontally away from its point of application? Will it move both vertically and horizontally and if so, can you estimate about how much will go in each direction? Figure 3 shows the effluent movement away from the at-grade unit for 4 different soil profile conditions.

e. Estimate the soil permeability based on the texture, structure and consistence. Do it for each layer of soil to the required depth beneath the proposed bottom of the system.

Horizontal and Vertical Separations:

Horizontal set backs from such features as wells and property lines are usually dictated by local codes and should be followed for all soil absorption systems. Most codes have required separation distances between the bottom of the aggregate and the high water table or bedrock. Table 1 gives the required distance of 3 ft for Wisconsin. Some codes may require only one foot of separation while some may require four feet of separation. The at-grade unit should follow the same separation distances as required for other soil absorption units.

Slopes:

Table 1 gives the slope limitation for at-grade systems. Limited experience is available for the steeper slopes. On the steeper slopes care must be taken to maintain safe construction practices as well as design.

Design Soil Loading Rate:

The design soil loading rate is based on the soil horizon that is in contact with the aggregate, which is the surface horizon for the at-grade system. Table 2 gives the recommended loading rates for various combinations of soil texture, structure, and consistence. These are estimates based on experience. Codes may dictate loading rates or area per bedroom based on the percolation rate. If percolation rates are required, then the rate should be determined for the most limiting horizon beneath the bottom of the system up to a distance of 3 ft (or code requirement) beneath the bottom of the system. Care should be used in sizing system absorption area based on percolation rates. If used, other criteria should also be used to make sure that the percolation rate is giving a reasonable absorption area. Table 3 gives sizing of absorption areas based on percolation rates.

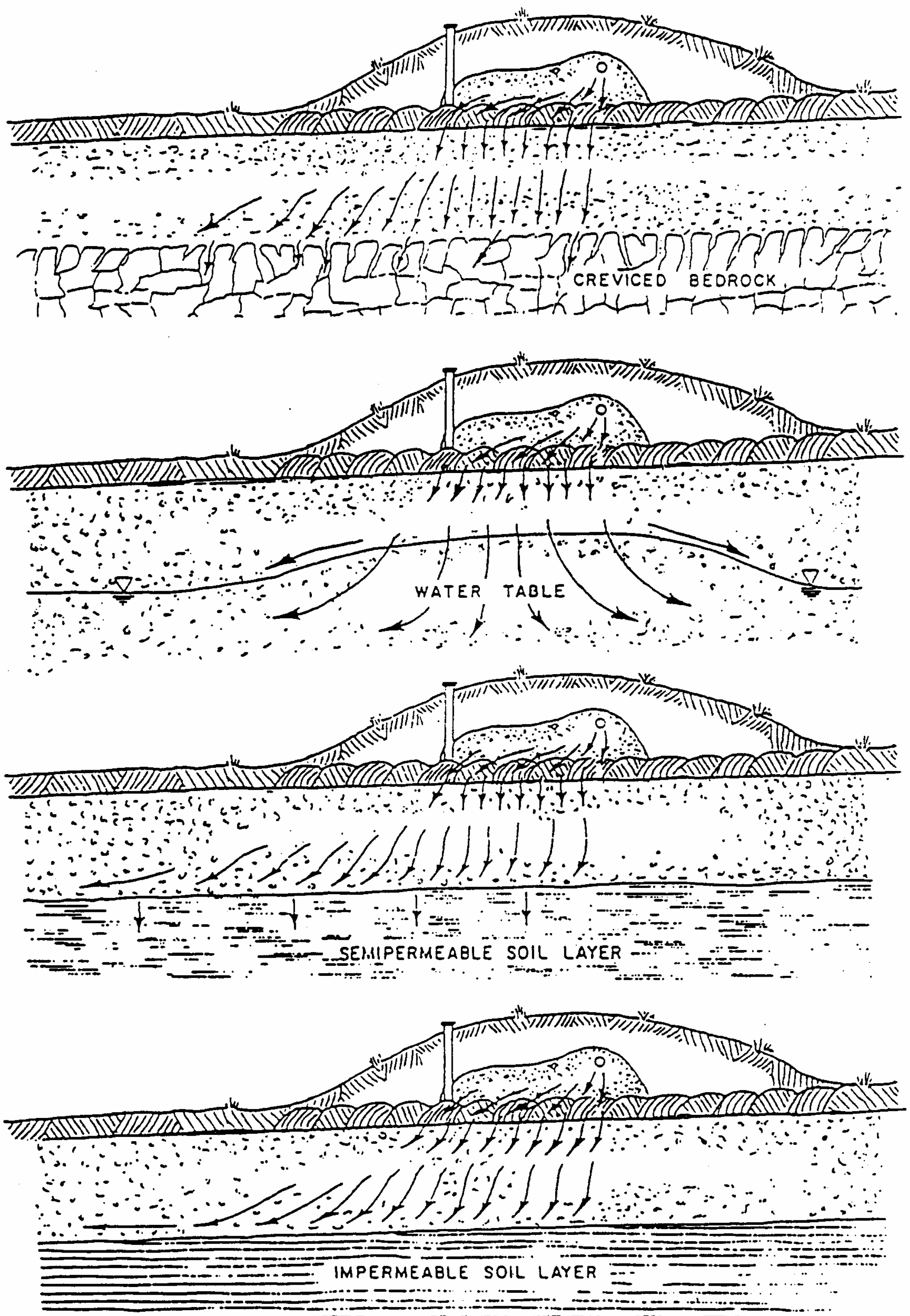


Fig. 3. Effluent Movement Away From the At-grade Unit Under Four Different Soil Profile Conditions

Table 1. Soil and Site Criteria for the Wisconsin At-Grade System Used in Wisconsin

Parameter	Limits
Depth from surface to high water[a]	> 3 ft
Depth from surface to bedrock	> 3 ft
Surface slope[b]	< 25 %
Permeability of soil (0-3 ft)	c
Flood plain	no

[a] May be seasonal which would be estimated by mottles. Wisconsin code sets 3 ft separation distance to limiting condition. Other codes may require other distances.
[b] Limited experience on 25% slope. Recent systems, not reported by Converse et al. (1988), have been placed on 25-30% slopes.
[c] The standard percolation test was not performed on the sites during the experimental phase (Converse et al., 1988). The estimated percolation rates for the surface horizon are between 0 and 60 mpi with the majority of the sites having rates of 30 mpi or faster.

DESIGN PRINCIPLES

System Configuration:

The system configuration must meet the soil site criteria and also fit on the site. As with other soil absorption systems, they should be designed long and narrow (Tyler and Converse, 1985; Converse and Tyler, 1986). Necessary design configuration may not fit on some sites thus requiring other alternatives. Prior to the design, the soil evaluator/designer must use the soil profile description to 1) estimate the effluent acceptance rate of the soil and 2) determine the flow path of the effluent as it moves through the soil profile and away from the system. For example, if there is a restrictive layer such as soil banding, hardpan, platy structure or high water table, the flow may be primarily horizontal and thus the design must be long and narrow (Fig. 3). If the platy structure is in the surface horizon or just below it, tilling will reorient the structure and should allow for vertical flow. If there is no restrictive layer, then the flow will be vertical and the effective width of the system may be greater. Unfortunately, it is very difficult to determine the exact effective width that the system should be. A system that is too wide may leak at the downslope toe or either toe on level sites. Other factors such as gas transfer and exchange beneath the absorption area (aggregate/soil interface) are also affected by the width of the system (Tyler et al., 1986). If there isn't sufficient length along the contour, but there is sufficient distance along the slope, configuration 3 and 4 in Fig. 4 may be appropriate for the site but only for at-grades using a pressure distribution network.

Effective Absorption Area:

The effective absorption area is that which is available to accept effluent. The effective length of the absorption area is the actual length of the aggregate along the contour. The effective width on sloping sites is the distance from the distribution pipe to the toe of the aggregate and on level

Table 2. Estimated Wastewater Design Soil Loading Rates for the Surface Horizon Based on Soil Morphological Conditions for Wisconsin At-grade Systems

	Soil Condition of Horizon in Contact with Aggregate (Instructions: Read questions in sequence. When the conditions of your soil match the question, use that loading rate and do not go further).	If Yes The Loading Rate In gpd/ft^2 Is:
A.	Is the horizon gravelly coarse sand or coarser?	0.0
B.	Is consistence stronger than firm or hard, or any cemented class?	0.0
C.	Is texture sandy clay, clay or silty clay of high clay content and structure massive or weak, or silt loam and structure massive?	0.0
D.	Is texture sandy clay loam, clay loam or silty clay loam and structure massive?	0.0
E.	Is texture sandy clay, clay or silty clay of low clay content and structure moderate or strong?	0.2
F.	Is texture sandy clay loam, clay loam or silty clay loam and structure weak?	0.2
G.	Is texture sandy clay loam, clay loam or silty clay loam and structure moderate or strong?	0.4
H.	Is texture sandy loam, loam, or silt loam and structure weak?	0.4
I.	Is texture sandy loam, loam or silt loam, and structure moderate or strong?	0.6
J.	Is texture fine sand, very fine sand, loamy fine sand, or loamy very fine sand?	0.6
K.	Is texture coarse sand with single grain structure?	0.8

sites it is the width of the aggregate (Figs. 1, 4 and 8).

Depending on the soil texture and other characteristics, the required absorption area can be determined using Table 2. The width is based on the linear loading rate acceptable to the site. The linear loading rate, which is defined as the loading rate per linear foot of system (gallons per day per linear foot along the contour (gpd/lf)), can be greater for deep permeable soils than for a shallow zone of permeable soil over a less permeable soil. Unfortunately it is difficult to estimate the linear loading rate for many soil

Table 3. Sizing of the Effective Area Based on Percolation Rates*

Soil Class	Sizing
(mpi)	(sq. ft / bedroom)
Class 1 (0 - 10)	165
Class 2 (10 - 30)	250
Class 3 (30 - 45)	300
Class 4 (45 -60)	330

*Taken from Wisc. Adm. Code (1985) on sizing using trench bottom area. The recommended approach to sizing is to use Table 2.

conditions but "good estimates" are suggested based on experience and judgement by the authors. If the flow away from the system is primarily vertical (Fig 4a), then the linear loading rate can be high but the recommended rate is below 10 gpd/linear ft otherwise the absorption area becomes excessively wide, especially on the slower permeable soils such as the silt loams to silty clay loams. However, if the more permeable soils are shallow and flow is primarily horizontal (Fig. 3d) then the linear loading rate should be constrained to 3-4 gpd/linear ft. This approach will normally result in systems that are narrow and therefore long.

<u>Total Length and Width</u>:

Once the effective length and width of aggregate/soil contact area are determined, it is necessary to add about 5 ft on each side and end of the aggregate to tie the system into the existing soil surface with the cover soil. Greater widths are satisfactory if additional landscaping is desired. However, use of heavy machinery on the downslope toe should be avoided especially if there is any horizontal movement of effluent caused by a slowly permeable horizon or high water table.

<u>Distribution Network</u>:

The at-grade system can be designed for either gravity or pressure distribution. The pressure distribution network requires a dose chamber while the gravity network does not as long as the pretreatment tank outlet is at a higher elevation than the distribution network. Because of the limited experience with gravity units, pressure distribution networks are being installed in all gravity units with the manifold being stubbed just outside the unit. If gravity distribution should not function properly, or if continued research shows they do not provide a reasonable length of service, the unit can be converted to pressure distribution easily. <u>At this time pressure distribution is preferred and recommended for at-grade systems</u>.

<u>Gravity Distribution</u>: Figure 5 shows the typical distribution pattern for both pressure and gravity flow. Typically in gravity flow, the effluent leaves the distribution pipe at one or two locations, moves vertically down

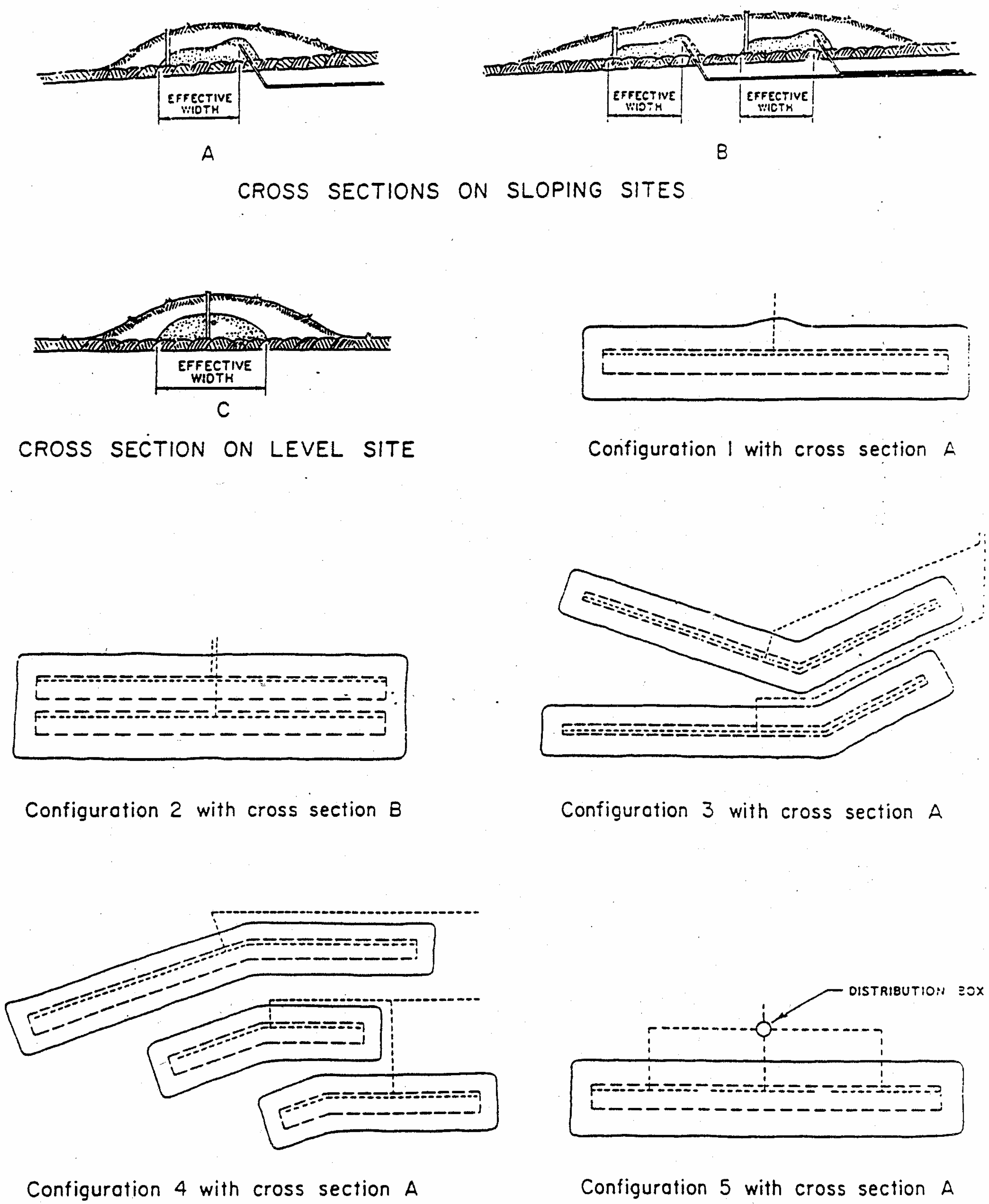
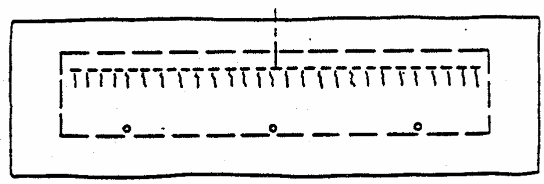
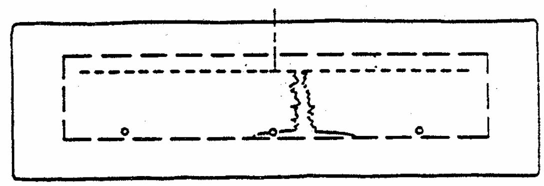


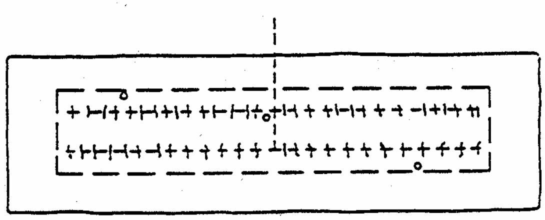
Fig. 4. Typical Configurations of At-Grade Units That Have Been Installed



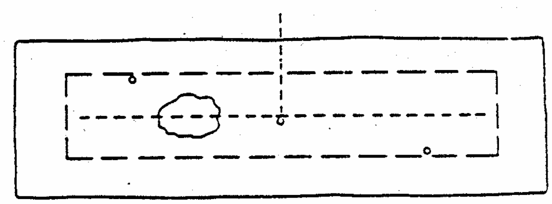
Pressure Distribution Using a Single Line on Sloping Site



Gravity Distribution Using a Single Line on Sloping Site



Pressure Distribution Using 2 lines On a Level Site



Gravity Distribution Using a Single Line on a Level Site

Fig. 5. Typical Distribution Patterns for Pressure and Gravity Distribution Networks

through the aggregate and then moves horizontally along the soil/aggregate interface until it infiltrates into the soil (Converse, 1974). As the clogging mat develops, the effluent will move further down the slope until it infiltrates. Eventually it will reach the toe of the aggregate and then it will move horizontally along the toe until it infiltrates. This phenomenon is called creeping clogging. Ponding will occur along the toe of the aggregate and may be observed in the observation tubes if the tubes are located downslope of where the effluent left the distribution pipe. If not, ponding will eventually appear in the observation tubes as the ponded effluent creeps along the toe of the aggregate. As noted in Fig 5, a large part of the effective infiltration area may not be used with gravity distribution on sloping sites.

On level sites, the effluent will spread out over the whole area just as it does in in-ground trenches or beds. Thus on some sites it may be appropriate to make the bottom of the absorption area level provided an acceptable separation distance between the bottom of the aggregate and the bedrock or high water table is maintained (Table 1). The system is then approaching a shallow in-ground system (Fig. 2) for which there is limited experience. Care must be taken not to reduce the infiltration rates in the soil due to construction practices. The effective infiltrative area must be quite level or the effluent will not flow to high areas until lower areas are excessively ponded. Sites that appear to be level may actually have a slight slope. In that case up to one half the absorption area may be ineffective if the system is designed as a level site.

If gravity flow is used, it must be restricted to the single absorption area configuration (Fig 4, configuration 1 and 5) as the effluent will enter one or the other absorption area unless provisions are made so the flow can be directed to either trench through a distribution box or drop box arrangement. In which case, all of the flow will be directed to one area until it is switched to the other area.

As the effluent ponds at the toe of the aggregate, seepage to the surface may occur resulting in raw effluent on the surface which must be avoided. This seepage will continue to occur until corrective action is taken. Corrective action includes converting the system to pressure distribution by connecting the pressure distribution network to a dose chamber (Fig 1) or by providing some means of diverting the flow from area to area in the system. This can be done by providing a distribution box up-slope of the at-grade unit (Fig 4, configuration 5) or providing diverting tees and risers where the pipe from the septic tank connects to the perforated distribution pipe (Fig 6). Figure 6 also shows the distribution of effluent as it is distributed to different parts of the system. The disadvantage of this approach, is that someone has to divert the flow occasionally. When done it will allow part of the system to rest.

<u>Pressure Distribution</u>: Pressure distribution is the recommended method of distribution of the septic tank effluent in the at-grade unit. Fig. 5 shows how the effluent is spread along the contour. The effluent leaves the lateral through the small diameter hole and moves vertically downward through the aggregate where it infiltrates into the soil. As it comes in contact with the soil, it will move laterally away (downslope on sloping sites and laterally in all directions on level sites) and infiltrates into the soil.

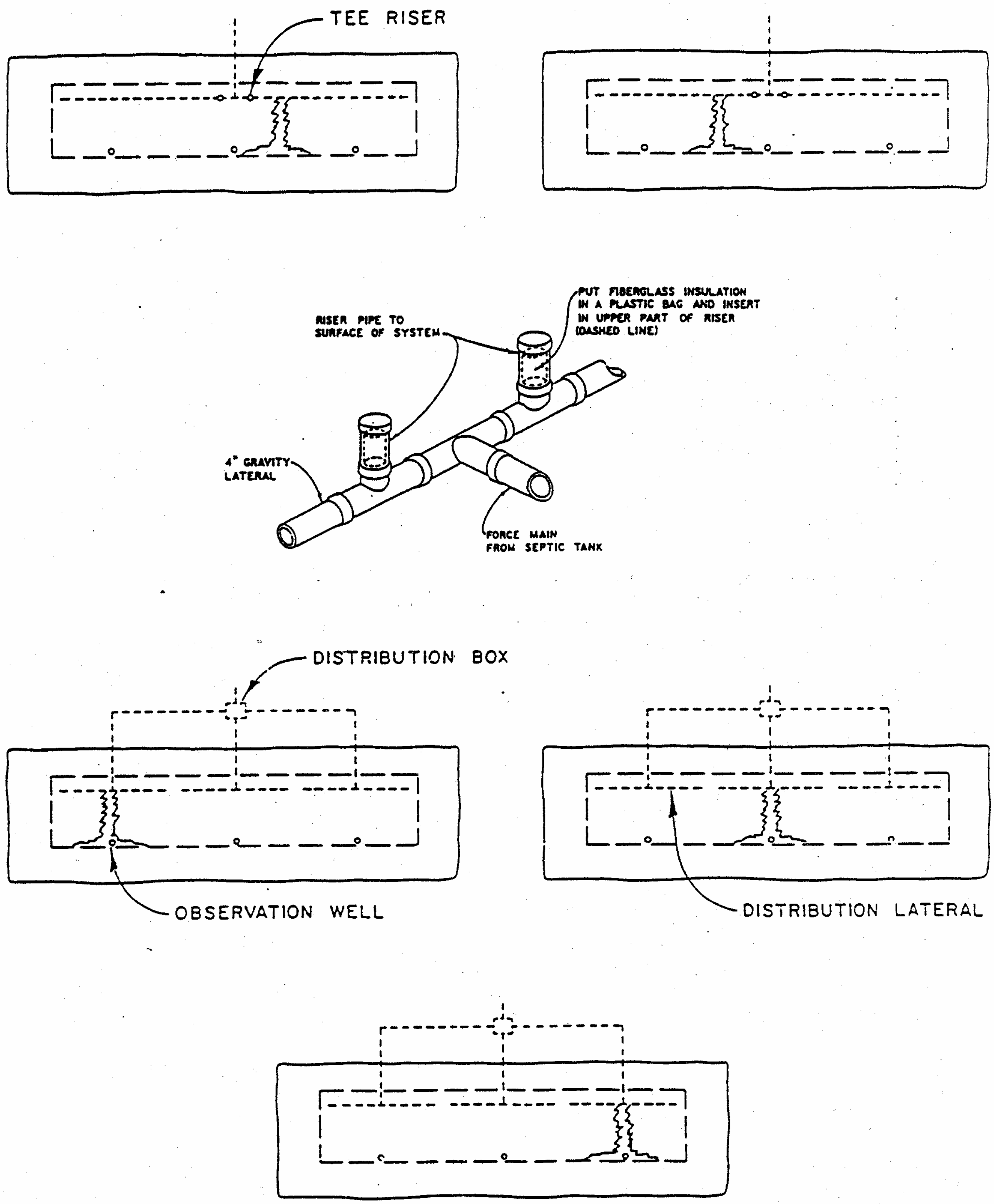


Fig. 6. Typical Distribution Patterns for Gravity Using Tees and Distribution Boxes

This approach should minimize the severe progressive clogging that typically occurs in gravity systems, but a clogging mat can occur in pressure systems.

The pressure distribution network configuration will vary depending upon the size and dimensions of the absorption area. For level sites with narrow absorption areas, a single lateral in the center along the length of the absorption area will suffice (Fig. 5). For wider absorption areas, it may be appropriate to use parallel laterals, fed by a manifold, and spaced equal distance apart so that the distance from the edge of the aggregate to the lateral is one half the distance of the spacing between the laterals and using a center manifold especially on longer units (Fig. 5).

On sloping sites for all systems, the distribution network consists of a single perforated pipe on the upslope edge of the aggregate with a center feed preferred (Fig. 5). For wider absorption areas on sloping sites, some contractors have installed parallel laterals with one lateral near the upslope edge and a parallel lateral midway down the slope. This approach has some validity in that it spreads the effluent over a wider area. If this approach is used and the slope is minimal, it is best to install the pipes level by placing more aggregate beneath the lower laterals. Designing pressure distribution networks for sloping sites is risky and provisions such as valves to equalize the flow to each lateral are recommended. Otis (1981) describes a procedure for designing a system for a sloping site.

The design of the pressure distribution network consists of 1) selecting the perforation diameter and spacing. 2) sizing the lateral length and diameter 3) selecting the number of laterals, 4) calculating the flow rate and dose volume, 6) sizing the force main, 6) sizing the pump based on head and flow rate, and 7) sizing the dose chamber. The design steps along with a design example are given in the appendix.

Observation Tubes:

Capped observation tubes, extending from the aggregate/soil interface to or above final grade, are placed in the absorption area provide easy access for observing ponding in the aggregate. Seepage at the toe of the unit, the result of excessive ponding, is the most probable cause of failure. On sloping sites the observation tubes must be placed just upslope of the downslope edge of the aggregate with the downslope edge of the tube at the edge of the aggregate. These observation tubes, consisting of 4 in. dia. PVC pipe with slots in the lower portion of the tube, must be stabilized so that they don't pull out when removing the cap. Fig. 7 shows three examples of stabilizing the observation tubes. The tubes can be cut off at final grade and recessed slightly to avoid being damaged by lawn mowers. Screw-type or slip caps are commonly used for the cover.

Cover:

After the aggregate, distribution pipe and observation tubes have been installed, a geotextile synthetic fabric is placed on the aggregate. Hay, straw or other material is not to be used in place of the fabric. Approximately one foot of soil cover is placed on the fabric and extended and tapered to a distance of at least five feet beyond the aggregate edge. The surface is seeded to vegetation to reduce erosion.

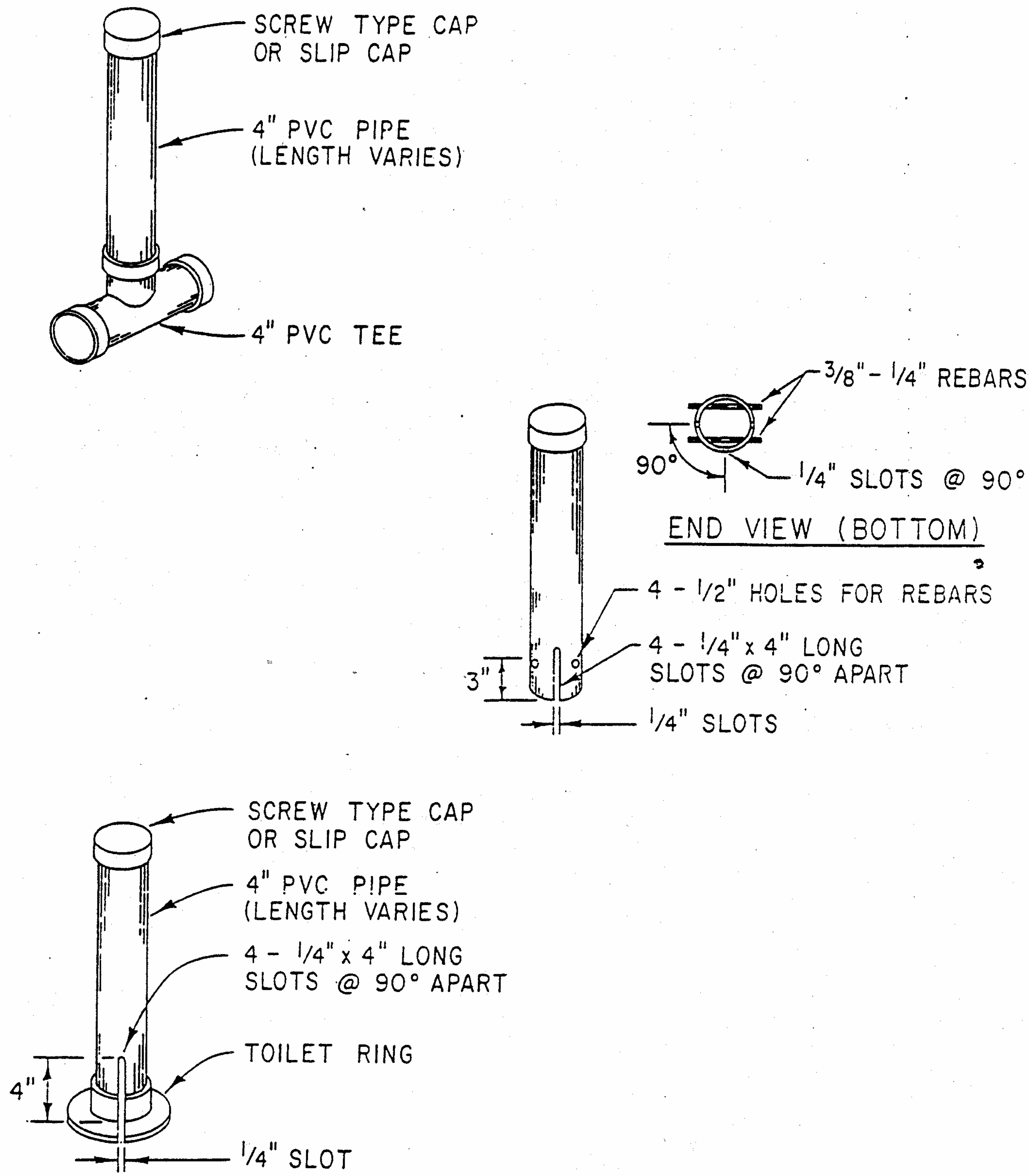


Fig. 7. Three Methods of Stabilizing Observation Tubes

DESIGN AND CONSTRUCTION EXAMPLE

Design:

When working with on-site wastewater treatment systems, the evaluator/designer must evaluate the soil site conditions and then select the best system for the site that meets the owner's needs and causes the least impact on the environment. When evaluating the site the following should be done (Refer to previous section on soil and site criteria for more detail):

1. Evaluate the landscape for surface water movement. Measure elevations and distances on the site so that slope, contours and available areas can be determined.

2. Describe several soil profiles where the system will be located. Determine the limiting conditions such as bedrock, high water table, and soil permeability.

The designer uses the information to design a system that will fit the site. Not all sites meet the criteria for on-site soil absorption systems and an alternative to soil absorption may be necessary.

Assume for the example the following site factors:

1. Soil profile is:

   0 - 12 in. sil; 10YR 6/4&2/1; moderate, medium, subangular blocky structure; friable consistence.
   12 - 24 in. sicl; 5YR 3/1; moderate, fine, subangular blocky structure; firm consistence.
   24 - 36 in. sic; 10YR 5/3; strong, medium, platy to massive structure; very firm consistence; many, medium, prominent mottles at 3 ft.

2. Slope is 20%.

3. Distance available along the contour is 175 ft and along the slope it is 30 ft.

4. Design for a 3 bedroom house.

Based on the above information, it appears that an at-grade system is suited for this site because estimated high water is at 36 in., the surface soil horizon is permeable, and code setback requirements are assumed to be satisfied.

Steps:

1. Determine the design flow rate (DFR).

   Since this is a 3 bedroom house, use 150 gallons per bedroom or a design flow rate of 450 gpd.

2. Estimate the soil loading rate (SLR) for the site.

   Use table 2 for selecting the appropriate soil loading rate (SLR) that matches the soil conditions. It is based on the soil horizon that is in contact with the aggregate. Since this is a silt loam with good structure and friable consistence, use a

   $$SLR = 0.6 \text{ gpd/ft}^2$$

   Note: In table 2 there is no mention of platy structure which will have a tendency do impede vertical flow. If the platy structure is in the surface horizon or slightly below and it can be tilled, the reorientation should allow the flow to move vertically through the horizon.

3. Estimate the linear loading rate (LLR) for the site.

   Evaluate the soil profile to estimate a linear loading rate. Since this profile consists of a permeable soil over a slowly permeable soil with massive structure, the flow will be primarily horizontal with some vertical flow (see Fig. 3c). Also, since the slope is fairly steep, a narrow system is appropriate. Based on experience and the discussion in the Design Principles section, an appropriate linear loading rate is:

   $$LLR = 4.0 \text{ gpd/lf}$$

4. Determine the effective absorption width (A) of the unit.

   Since the estimated linear loading rate is 4 gpd/ft and the soil loading rate is 0.6 gpd/ft^2 then:

   $$\begin{aligned} A &= LLR \;/\; SLR \\ &= 4 \text{ gpd/ft} \;/\; 0.6 \text{ gpd/ft}^2 \\ &= 6.7 \text{ ft} \end{aligned}$$

   This is the effective width of the aggregate. If this was on a non-sloping site, then the total aggregate width would be 6.7 ft. Since this is on a sloping site, the total aggregate width will be about 8.0 - 9.0 ft as approximately 1.5 to 2 ft of aggregate must be placed upslope of the distribution pipe to support the distribution network and satisfy the angle of repose of the aggregate (Fig. 1 and 8).

5. Determine the absorption length (B) of the unit.

   The length of the absorption area (B) is dependent on the design flow rate (DFR) and the linear loading rate (LLR) then:

B = DFR / LLR

= 450 gpd / 4 gpd/lf

= 112 ft

Thus the effective absorption area is 112 ft by 6.7 ft or 750 ft^2.

6. Determine the configuration of the system that best fits the site.

   Once the effective width and length of the absorption area are determined, the designer must determine how it will best fit on the site. On some sites it may be necessary to divide the absorption area into several units if there isn't sufficient length along the contour. Fig. 4 show various configurations that have been used. The most common is the single unit that is placed on the contour. On some sites it may be necessary to build several parallel units using alternating pumps to dose each unit or design a pressure distribution system for a sloping site.

7. Determine the overall length (L) and width (W) of the unit.

   It is necessary to tie the aggregate into the surrounding soil surface by placing soil about 5 ft wide around the perimeter of the aggregate (Fig. 1 and 8). Greater widths for landscaping purposes are satisfactory.

   L = absorption length (B) + soil cover end lengths

   = 112 ft + 5 ft + 5 ft

   = 122 ft

   W = absorption width (A) + upslope width of aggregate (C) + soil cover side widths

   = 6.7 ft + 2 ft + 5 ft + 5 ft

   = 19 ft

8. Determine the height of the unit.

   Design for a minimum of 6 in. of aggregate beneath the distribution pipe and about 2 in. above the pipe. As shown in Fig. 8a, the aggregate will taper off at the edges. Place synthetic fabric over the aggregate and approximately 1 ft of soil cover over the fabric. Thus the height of the unit above the original grade will be approximately 2 ft at the distribution lateral and tapering to the edges.

9. Design a distribution system for the unit.

   Since the absorption area is relatively narrow and on a slope, a single distribution line along the length is satisfactory. It would be located 6.7 ft upslope of the aggregate toe. If the site was level, the distribution pipe would be located in the center of the aggregate. The distribution can either be gravity or pressure but pressure distribution is recommended.

Gravity: If gravity is used, provisions should be made so the flow can be diverted to at least 2 locations within the unit either using two vertical risers near the center inlet tee or use a distribution box as shown in Fig. 6. The gravity laterals consist of 4" perforated PVC drain pipe preferably with a center inlet. One distribution lateral along the length of the absorption area for gravity is sufficient regardless of the width of the absorption area. A pressure distribution line should be installed next to the gravity distribution line because gravity distribution in these systems has not been proven with time. If several absorption areas are installed (Fig. 4, configuration 2, 3 or 4) gravity distribution is not recommended.

Pressure: Design the pressure network as per procedure outlined in the appendix. Normally the network consists of a single lateral along the length of the absorption area. On wider absorption areas, some have installed several parallel laterals (Fig. 5) but only on relatively low slopes. Care must be taken to get equal distribution in the laterals if they are not at the same elevation.

Construction:

As with all soil absorption systems, proper construction is very important. The following steps should be followed when constructing the at-grade unit. There are variations to this approach, but the principles should be followed closely.

Steps:

1. Lay out the system with the length following the contour.

2. Cut all grass, brush and trees just above ground surface and remove. Do not remove tree stumps. In wooded areas rake off dead vegetation if over an inch thick. Avoid heavy vehicle traffic on the site.

3. Check for proper soil moisture prior to construction. For single grain soil, such as sand, the moisture content is not as critical as for structured soil. The soil is too wet to till if it takes on a wire form when rolled between the hands.

4. Till the area following the contour to a depth of 6 to 8 in. The tilled area should be at least the total length and width of the system. A mold board plow, chisel plow, or chisel teeth mounted on a backhoe bucket are satisfactory for tillage. The normal teeth on a backhoe are not satisfactory and must not be used. Chisel teeth, mounted on a backhoe, is the preferred method as it is easier to till around boulders and tree stumps. It also allows for deeper tilling to break up platy structure. A rototiller may be used (but not recommended) for single grain soils, such as sand, but not for

structured soils. Care must be taken not to compact and smear the soil during the tillage operation. Driving on the tilled area can rut and compact the soil and is not recommended.

5. Install the inlet pipe from the pretreatment unit or dose chamber from the upslope side either prior to plowing or after plowing. If it enters from the downslope edge or if the site is level, place the pipe <u>prior</u> to tilling with minimum disturbance of the downslope edge of the system. Bring the force main in at right angles to the absorption area and connect to the upslope end (preferably) of the manifold and not the center of the manifold if a manifold is used.
   Do not bring the force main in from the end of the absorption area to the center of the system as this would destroy the soil structure beneath the absorption area. If required to come in from the end, use either an end feed or bring the force main in on the upslope side of the absorption area.

   Avoid traffic on the tilled area especially beneath the aggregate area and downslope. If compaction or ruts occur in the upslope or downslope area during construction, retill the compacted or rutted area. Minimize the subsoil disturbance beneath and downslope of the absorption area.

6. Place the three observation tubes at 1/6, 1/2, and 5/6 of the absorption length and <u>exactly at the toe of the aggregate</u>. The tubes must be constructed and placed so that ponded effluent at the downslope edge of the aggregate may be observed in the tubes. Stabilize the observation tubes (Fig. 7).

7. Place the aggregate in the designated area of the tilled area to a depth of 6 in. Work from the upslope edge of the system.

8. Place the distribution network level along the length of the unit and connect it to the inlet pipe from the pretreatment unit or dose chamber. Place 2 in. of aggregate on top of the network.

9. Place non-biodegradable geotextile synthetic fabric (not building paper, burlap, hay or straw) over the aggregate. Extend it only to the edge of the aggregate.

10. Place approximately 12 in. of soil over the fabric and taper it to a distance of at least 5 ft in all directions from the aggregate. Finish grading round the system to divert surface water away. Seed and mulch the exposed areas immediately after construction to control erosion.

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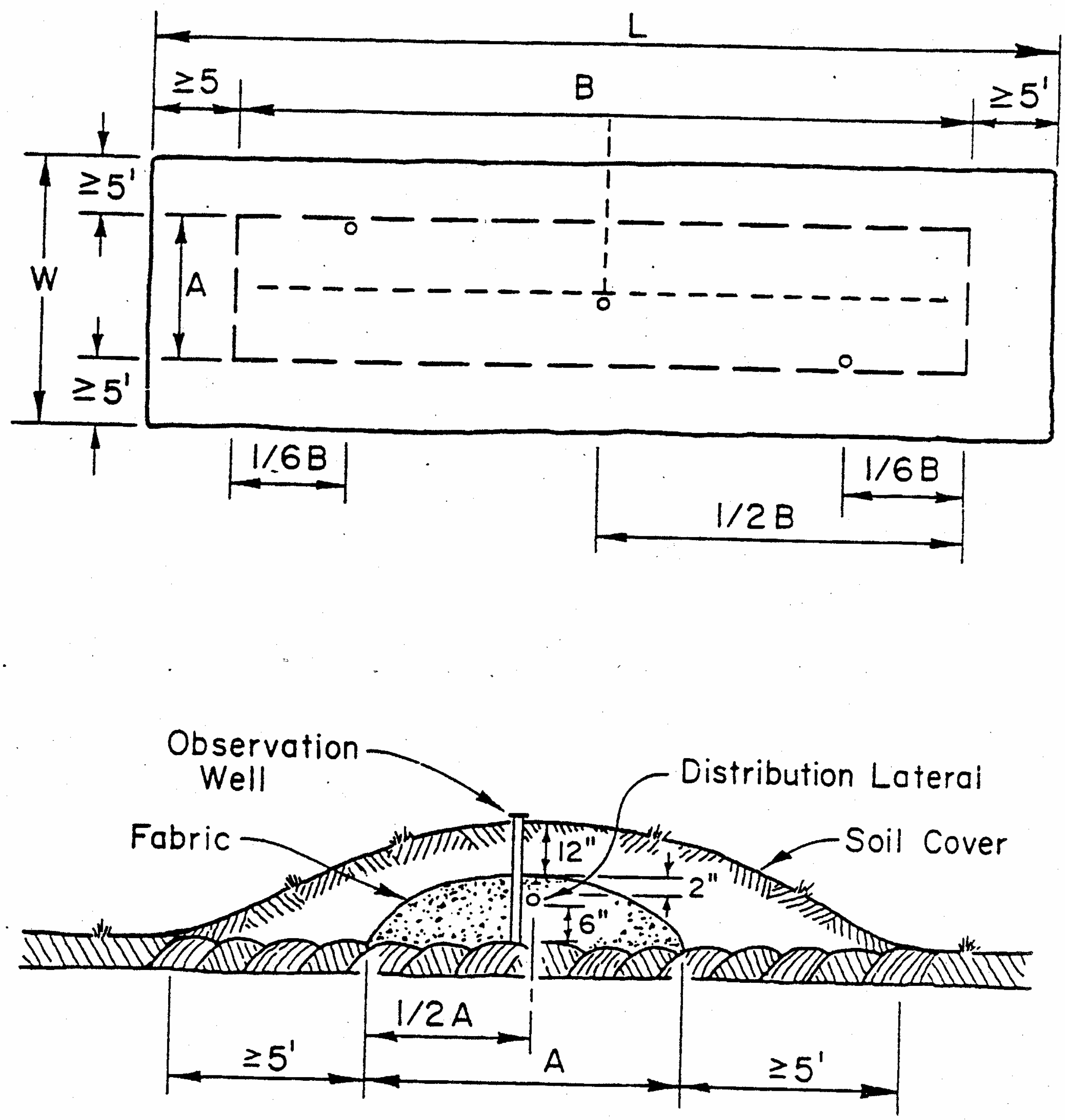
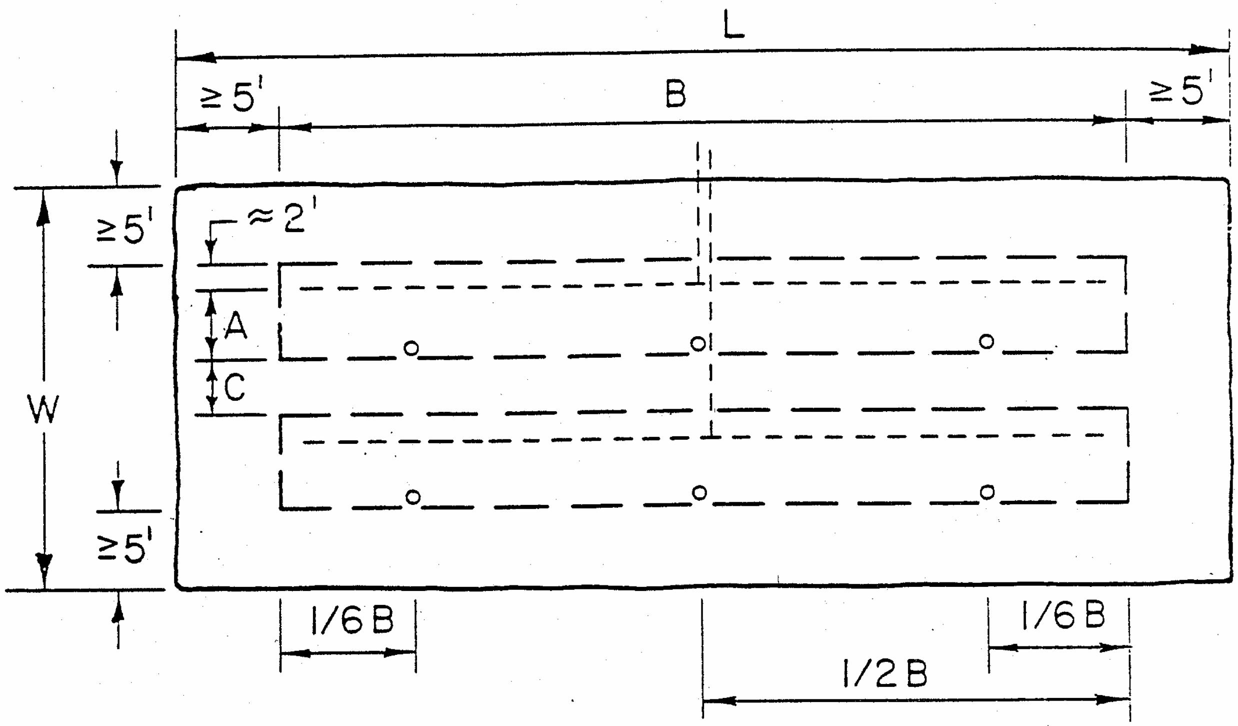


Fig. 8b. Plan View and Cross Section of a Wisconsin At-grade Unit with an Single Soil Absorption Area on a Level Site



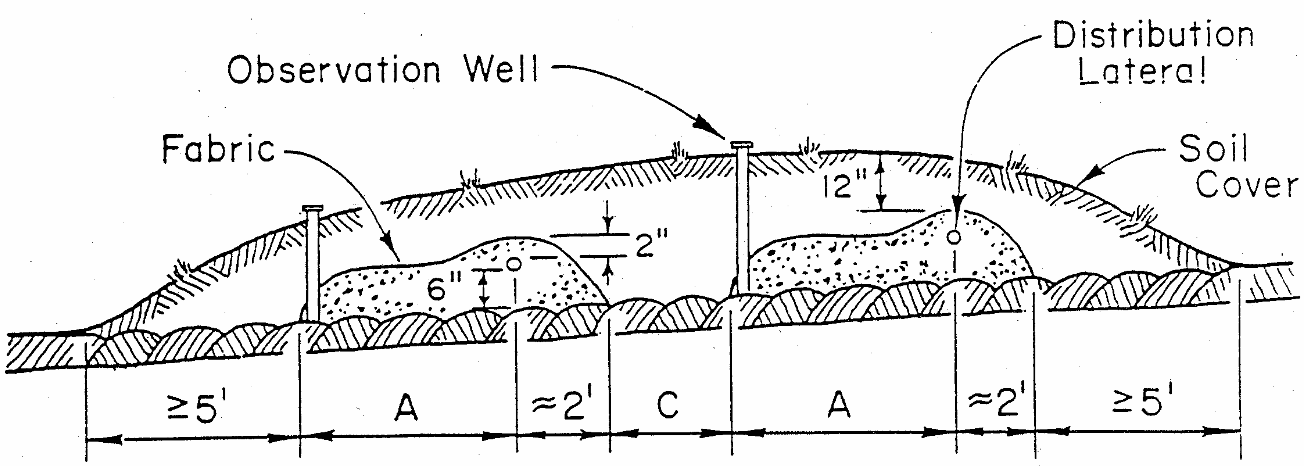


Fig. 8c. Plan View and Cross Section of a Wisconsin At-grade Unit with Two Absorption Areas With in a Single Unit on a Sloping Site

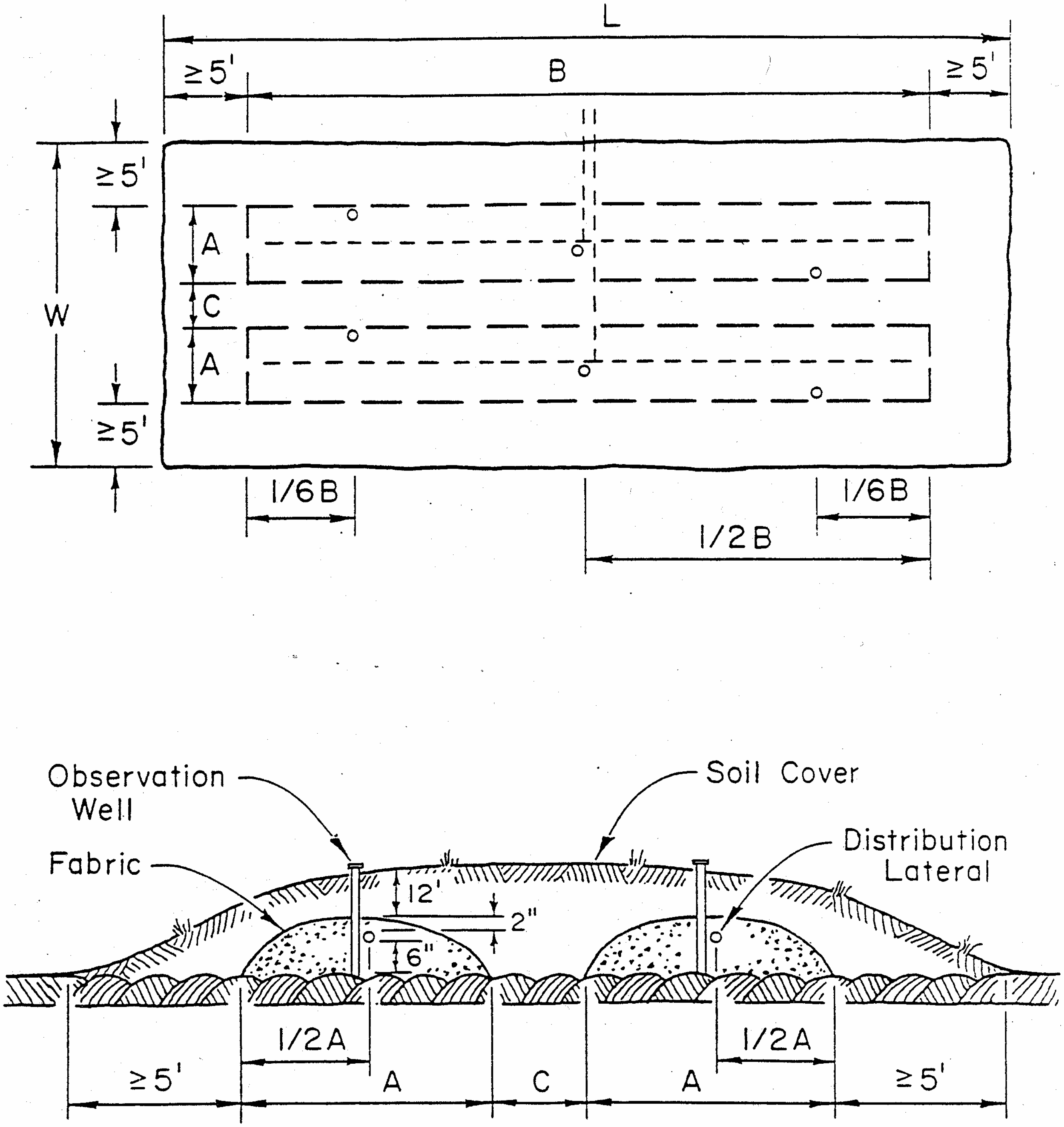


Fig. 8d. Plan View and Cross Section of a Wisconsin At-grade Unit with Two Absorption Areas Within a Single Unit on a Level Site

WISCONSIN MOUND SOIL ABSORPTION SYSTEM:

SITING, DESIGN AND CONSTRUCTION MANUAL

BY

James C. Converse E. Jerry Tyler[1]

January , 2000[2]

The Wisconsin mound wastewater soil treatment system was developed in the 1970s to overcome some limitations of in-ground trench and bed units and the Nodak system (Witz, 1974). The objective of the mound, as with other soil-based units is to treat and disperse domestic and commercial wastewater on-site via subsurface in an environmentally acceptable manner and to protect the public health.

The Wisconsin mound has been widely accepted and incorporated in many state and local regulations. In 1980 it was incorporated into the Wisconsin Administrative code. Mound technology was successfully implemented in Wisconsin partially because of an extensive educational program offered during the introduction of the mound concept. For the mounds to continue as a viable "tool" in treating and dispersing on-site wastewater, the soil evaluator, designer, installer, regulator and manager must understand the principles of operation, design, installation and management of the system.

Mounds in some areas have not been as successful as in Wisconsin, primarily because of the lack of trained professionals and/or unproven design modifications. Education of all parties involved is essential and care must be taken when making modifications.

Figure 1 shows the components of a Wisconsin mound system. It consists of a septic tank, a dosing chamber and the mound. The septic tank removes solids by settling and floatation with some of the solids transformed into soluble material, which pass to the dosing chamber. The

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respectively, of Small Scale Waste Management Project. Research supported by the College of Agricultural and Life Sciences.

[2] This is an updated version of the 1990 mound manual with the same name. It should be used in place of earlier versions.

NOTE: Names of products and equipment mentioned in this publication are for illustrative purposes and do not constitute an endorsement, explicitly or implicitly.

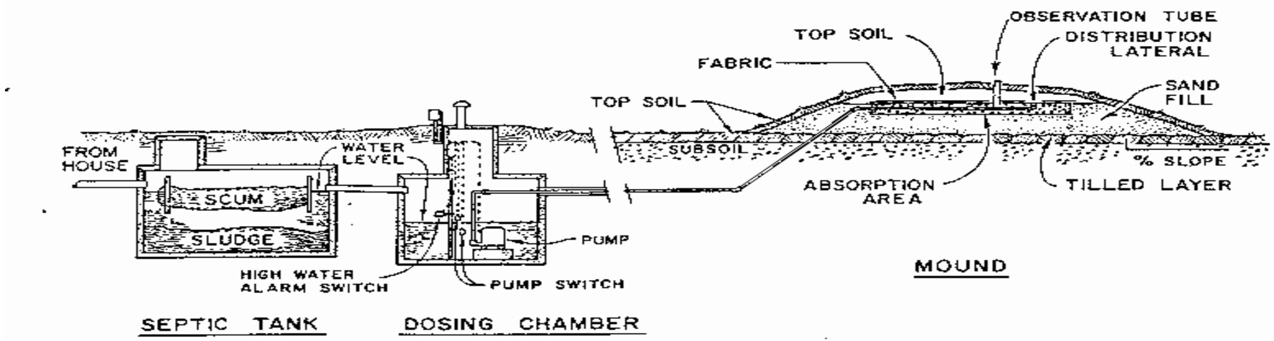

Fig. 1. Schematic of the Wisconsin mound system showing septic tank, dosing and mound.

dosing chamber contains a pump or siphon, which transfers effluent, under pressure to a distribution network of small diameter pipes with small perforations which distributes the effluent uniformly over the absorption area of the mound. The effluent infiltrates into and percolates through the mound sand and native soil, the pathogens are removed, the organic matter is assimilated, nitrogen is transformed to nitrate and phosphorus is retained in the native soil and may slowly migrate depending on the soil properties.

Originally, the Wisconsin mound was designed for specific soil and site limitations for wastewater flows of less than 750 gpd (Converse et al., 1975 a, b, c; Converse, 1978). Based on further research and evaluation, the mound technology was expanded to larger systems and more difficult soil and site conditions (Converse and Tyler, 1986a and b; Tyler and Converse, 1985; and Converse and Tyler, 1987). The new criteria were incorporated into a siting, design and construction manual (Converse and Tyler, 1990). Many changes have taken place in on-site technology recently especially in sand filter technology. Since the mound is a combination of a single pass sand filter and dispersal unit, many of the sand filter research findings should be implemented into mound technology. **Thus, the purpose of this publication is to incorporate new findings into the siting, design and construction of mounds receiving septic tank effluent.**

WASTEWATER SOURCE

The wastewater quality and quantity is extremely important to ascertain before designing a soil based on-site wastewater treatment system. The design and performance of the mound system, as well as other soil based treatment systems, is based on typical domestic wastewater which has been pretreated by passing the wastewater through a septic tank. Typical domestic effluent will have a biochemical oxygen demand (BOD) in the range of 150 - 250 mg/L and total suspended solids (TSS) in range of 50 – 100 mg/L. Fats oils and greases (FOG) are typically below 15 mg/L. These numbers will vary somewhat depending on household activity, water conservation activities and the biological activity in the septic tank.

The mound is suitable for final treatment and dispersal of highly pretreated effluent from such units as aerobic units, sand filters, peat filters and biofilters which typically produce effluent with BOD and TSS less than 25 mg/L. For this quality of wastewater, the sand-loading rate can be increased over that used for septic tank effluent and the separation distance can be reduced depending on code requirements. Current thinking is to double the loading rate and reduce the separation distance by 12" (Wisc. Adm. Code, 2000).

High strength wastewater, such as from restaurants, must either 1) be pretreated to similar BOD, TSS and FOG strengths of septic tank effluent from domestic wastewater before it is applied to the mound or 2) the loading rate to the sand must be reduced significantly so that the organic loading rate to the mound is at or less than that from domestic wastewater. Extreme care must be exercised when working with non-domestic wastewater.

The design loading rates are based on 150 gpd/bedroom resulting in 450 gpd for a 3-bedroom home. If the mound, as well as other soil-based units, is loaded at 450 gpd on a regular basis, it will likely fail. The daily average flow is expected to be no more than about 60% of design or 270 gpd. If water meter readings are used in the design process, the design flow rate must be adjusted upward by at least the same percentage or typically 1.5 – 2 times the meter reading.

The focus of this publication is on domestic septic tank effluent. Adjustments can be made to the design for the highly pretreated effluent and high strength wastes as previously stated.

PRETREATMENT

The septic tank serves as a pretreatment unit for all soil absorption units, including the mound, and its primary function is to remove solids via settling and floatation. New technologies can be incorporated into the septic tank with the most common being effluent filters and pump vaults. Converse (1999) provides information relative to effluent filters and other components related to septic tanks. The dosing chamber/vault is also an essential component to the mound system. It provides a home for the pump and controls, stores effluent and can provide extra storage during down time. With new technology, pump vaults can be incorporated within a septic tank, thus eliminating a tank. The following are several options available for consideration (Converse, 1999):

1. A single compartment septic tank with an effluent filter followed by a single compartment pump chamber.

2. A double compartment tank with the first compartment containing an effluent filter serving as the septic tank and the second compartment serving as the pump chamber.

3. A double compartment tank with both compartments serving as a septic tank with an effluent filter at the outlet of second compartment followed by single compartment pump chamber. This may be the desired alternative as a modified aerobic unit, such as a Nibbler Jr. (NCS, 1998) or similar product, could be placed in the second compartment to reduce the organic load to the mound if the mound should ever develop a clogging mat, pond or breakout. The conversion would cause minimal disturbance, as a tank is already available. Converse et al., (1998) discuss renovation of clogged soil absorption units utilizing aeration.

4. A single compartment tank with a pump vault within the septic tank. The effluent filter is incorporated into the pump vault that suspends from the outlet of the septic tank. An alternative is a double compartment septic tank with a hole in the center of the middle wall to connect the two compartments together in the clear zone and the pump vault in the second compartment. This unit will not provide extra storage capacity as with the individual tank.

Recent research on single pass sand filters shows that short frequent doses to the sand filter with closely spaced orifices (4 – 6 ft^2/orifice) improves effluent quality (Darby et al., 1996). Short frequent doses require time dosing instead of demand dosing. Most mounds are demand dosed with larger areas/orifice of 15 to 20 ft^2/orifice. This results in a large quantity of effluent discharged at once and applied less uniformly on the infiltrative surface than for sand filters. This large quantity of effluent moves through the sand rapidly (assuming no ponded condition), allowing insufficient time for the biota to cleanse the effluent totally. This forces fecal coliforms and pathogens further into the soil profile. Short frequent doses and more closely space orifices allows the effluent to be retained in the sand/soil for longer periods. Converse et al., (1994) suggested that the reason for some fecal coliforms found deep in the soil profile beneath mounds was due to large infrequent doses. **Designers should use smaller doses and more closely spaced orifices. They should consider time dosing in distributing the effluent to the mound.** Timed dosing requires that surge capacity be incorporated into the septic tank and/or pump chamber to sore the peak flows until it is dosed into the mound and requires control panels which have become very user friendly. Converse (1999) discusses the various options including pump vaults, effluent filters and time/demand dosing. Pressure distribution and dose volumes are discussed in detail by Converse (2000).

SITING CRITERIA

A designer of on-site wastewater treatment and dispersal systems must have a basic understanding of wastewater movement into and through the soil. The designer should work closely with the site evaluator to make sure he/she understands how effluent will move into the soil and away from the system. This understanding is based on information collected during the site evaluation.

Figure 2 shows a schematic of effluent movement within and away from mound systems under various soil profiles. Depending on the type of profile, the effluent moves away from the unit vertically, horizontally or a combination of both. These concepts are true for all on-site systems.

The siting and design concepts presented here and elsewhere results in soil treatment/dispersal units that are long and narrow (Converse et al., 1989; Tyler et al., 1986). The more restrictive the soil profile, the narrower and longer the soil treatment/dispersal unit will be. If these concepts are not followed, then the system may not perform as expected. **The sizing and configuration of all soil absorption units, including the mound, is based on how the effluent moves away from the unit and the rate at which it moves away. Not all of these concepts will apply to all soil and site conditions, as soil treatment/dispersal units are not compatible to all sites and should not be used on such sites.**

Separation distances:

Codes, regulating on-site systems, require a depth of soil or soil and sand fill to treat effluent before it reaches a limiting condition such as bedrock or high water table or other restrictive layers. Figure 3 shows the relationship between the type of system best suited for the site and the
location of the limiting condition beneath the ground surface where 3 feet of separation is required. This figure can be used for other separation distances, which may vary from 1–4 feet depending on the code requirement.

For the mound unit, this separation distance consists of the distance from the ground surface to the limiting condition below the ground surface plus the depth of sand between the ground surface and the infiltrative surface within the mound (sand/aggregate interface or the exposed surface of chamber units). For example, if the code requires 3 feet of suitable soil and the limiting condition is 20" beneath the ground surface, the sand fill depth between the ground surface and the infiltrative surface is 16" for mounds receiving septic tank effluent.

Distance to Water Table:

A distinction should be made between permanent water table and seasonal saturation. Seasonal saturation is the depth at which the soil is saturated for a period of time (days to weeks) primarily during the spring months. This may occur at other times during wet periods and at other locations. Permanent water table relates to a water table that is present all the time. The level

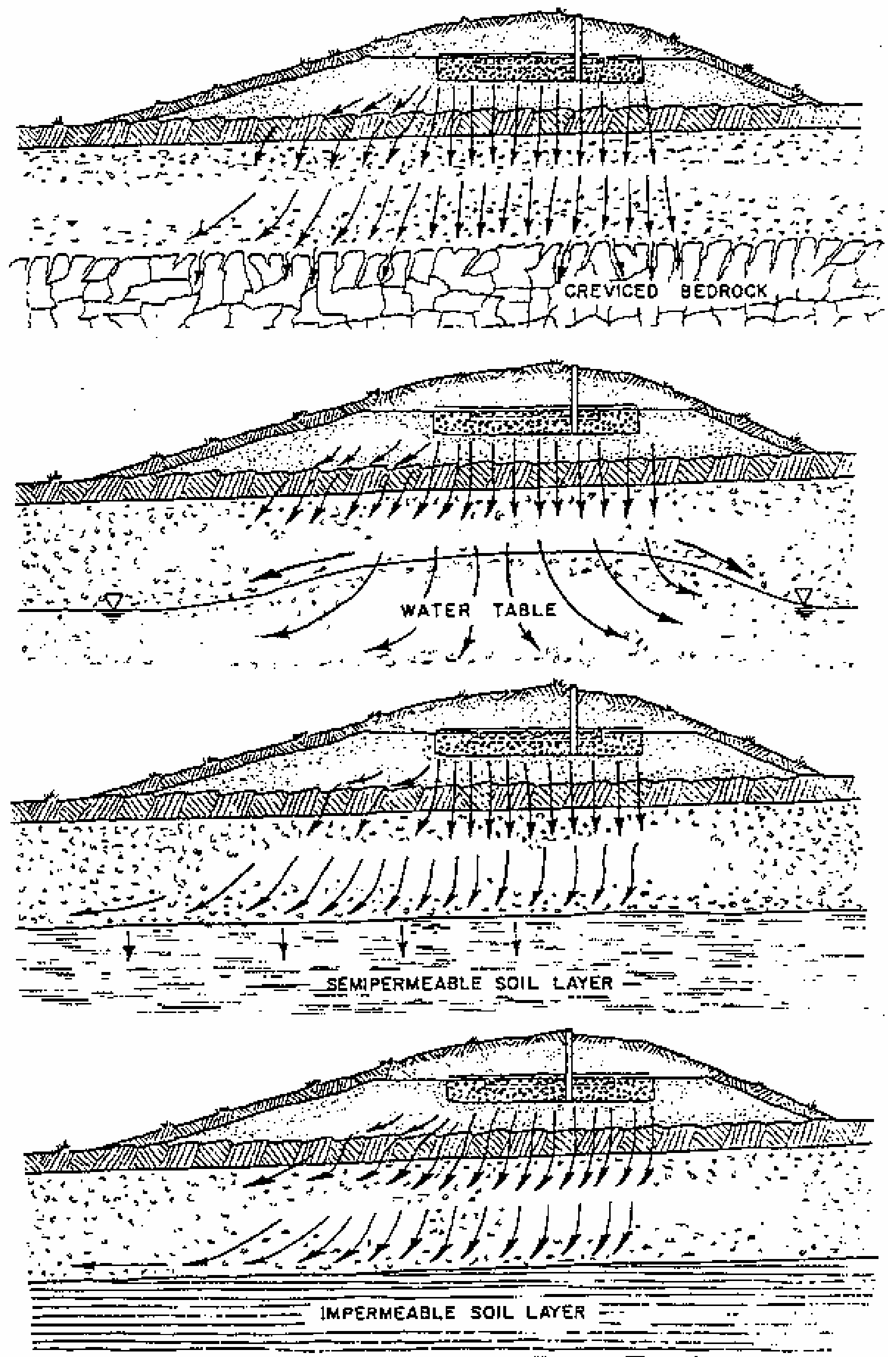

Fig. 2. Effluent movement within and away from the Wisconsin mound for four different types of soil profiles.

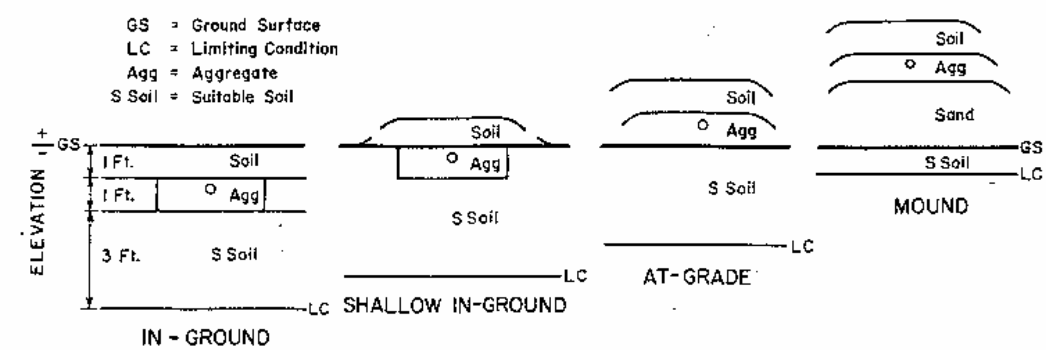

Fig. 3. Cross section of four soil absorption units in relation to ground surface and limiting conditions.

may vary depending on precipitation and other factors. All research relating to mounds has been done on seasonally saturated sites. This is important to understand as mounds may perform differently when placed on sites with permanent water table than on sites with shallow seasonal saturation. For example, stress at the toe will be more continuous with a shallow permanent high water table than with seasonal saturation.

Seasonal saturation is determined by 1) redoxmorphoric features (soil color, grays and reds, previously known as mottles) or 2) direct observation via a soil boring or observation wells. Landscape features and native vegetation type also give an indication of soil moisture conditions. If the redoxmorphoric features extend into the topsoil, it is difficult to estimate the distance of seasonal saturation beneath the ground surface as it is impossible to detect redoxmorphoric features because of the predominate blackish color in the topsoil. In these situations direct observation is the best method but the window of opportunity is very limited.

During seasonal saturation the mound is under stress and there is the possibility of toe leakage. Leakage will be a function of the saturation depth, soil permeability, soil loading rate, and linear loading rate. In Wisconsin, very few mounds have had toe leakage because mounds are long and narrow on sites with high potential for toe leakage. The recommended depth to seasonal saturation is 10 in. beneath the ground surface (Table 1). It is extremely important to note that as the depth to seasonal saturation decreases (<10 in.), the chance of toe leakage during seasonal saturation increases greatly. To minimize toe leakage under these conditions, the linear loading rate (to be discussed later) must be decreased resulting in longer mounds. The mound will also be taller to compensate for the reduced soil separation distance.

Table 1. Recommended soil and site criteria for the Wisconsin mound system.

Parameter	
Depth to high water table	10 in.
Depth to crevice bedrock	24in.[a]
Depth to non-crevice bedrock	10 in.
Permeability of top horizon	0.3 gpd/ft^2
Site Slope	Note[b]
Filled site	Yes[c]
Over old system	Yes[d]
Flood Plain	No

[a] Depth recommended if the crevices are open. If the crevices are filled with soil, may consider reducing depth to 18”

[b] Note: Slope is not a factor in the performance of mound. Slope may be limited due to safe construction techniques.

[c] Suitable according to soil criteria (texture, structure, consistence).

[d] The area and back fill must be treated as fill as it is a disturbed site.

Depth of Bedrock:

Bedrock should be classified as crevice, non-crevice semi-permeable, or non-crevice impermeable. Bedrock has been defined where at least 50% of the material by volume is rock (Wisc. Adm. Code, 1983). Once the effluent reaches the bedrock, treatment may or may not take place depending on the bedrock characteristics. In crevice bedrock where the crevices are filled with soil the flow is concentrated in the crevices which may reduce treatment effectiveness but it will be more effective than bedrock with open crevices. Therefore, some credit should be given to filled crevices (see footnote a in Table 1).

Soil Permeability:

Table 2 gives the recommended soil loading rate based on soil texture and structure for the mound basal area. This table assumes that the soil consistence is loose, friable or firm and not very firm. In very firm conditions, water movement is very slow and the site is not
recommended for mound placement. Since the basal area receives effluent low in BOD and TSS, the loading rate can be increased compared to soils receiving septic tank effluent. In the past effluent quality has not been taken into consideration when sizing the basal area and the soil loading rates have been the same as for septic tank effluent. This change will reduce the basal area required but will be more in line with loading rates of highly pretreated effluent. In most cases the mound footprint will not change because of the recommended 3:1 side slopes. The 3:1 slope was selected for mowing safety.

Slopes:

Site slopes are not a limitation for on-site soil units. Slope limitations are primarily for construction safety concern. Systems on steep slopes with slowly permeable soils should be long and narrow to reduce the possibility of toe leakage. A 2 % limit is recommended which is based on construction concerns (Table 1) and not soil and hydraulic properties.

Filled areas:

Fill is defined as the soil placed to raise the elevation of the site. Textures range from sand to clay or a mixture of textures. Structure is often massive (structureless) or platy. Under these circumstances the permeability of the soil is reduced and variable. A more intensive soil evaluation must be done because of the increased variability encountered in filled sites over naturally occurring sites. Many more observations are generally needed for filled sites compared to non-filled sites and the site evaluator must be knowledgeable of the ramifications of fill.

Flood Plains:

It is not recommended to install any soil absorption system in a flood plain, drainage ways or depressions unless flood protection is provided.

Horizontal Separation Distances:

The same separation distances used for other soil based dispersal units should be used for the mound unit. On sloping sites the up slope and end distances should be measured from the up slope edge or ends of the aggregate to the respective features and the down slope distance should be measured from the down slope toe of the mound to the respective features. As with all soil based dispersal units on sloping sites where the flow away from the unit is primarily horizontal, a greater down slope horizontal separation distance may be appropriate to avoid weeping into a ditch or basement that may be located down slope.

Sites with Trees and Large Boulders

Generally, sites with large trees, numerous smaller trees or large boulders are less desirable for mound systems because of the difficulty in preparing the site. If a more desirable site is not available, the trees must be cut at ground level leaving the stumps in place. Boulders should not be removed. If the tree stumps and/or boulders occupy a significant amount of the surface area, (in most cases they do not) the size of the mound basal area should be increased to provide sufficient soil to accept the effluent. The site evaluator should provide location and size information about trees and boulders.

Table 2. Design basal loading rates for mound systems for soil horizons with loose, very friable, friable and firm consistence. These values assume wastewater has been highly pretreated with BOD and TSS < 25 mg/L and based on 150 gpd/bedroom.

	Structure					
	0		pl		bk, pr or gr	
Texture	sg	m	1	2&3	1	2&3
	--------------gpd/ft^2----------------------					
cos	1.6	-	-	-	-	-
s	1.2	-	-	-	-	-
fs	0.9	-	-	-	-	-
vfs	0.6	-	-	-	-	-
lcos	1.4	-	-	-	-	-
ls	1.0	-	-	-	-	-
lfs	0.9	-	-	-	-	-
lvfs	0.6	-	-	-	-	-
cosl	-	0.6	0.5	0.0	0.7	1.0
sl	-	0.5	0.4	0.0	0.6	0.9
fsl	-	0.5	0.4	0.0	0.6	0.8
vfsl	-	0.4	0.3	0.0	0.6	0.8
l	-	0.5	0.5	0.0	0.6	0.8
sil	-	0.2	0.3	0.0	0.3	0.8
si	-	0.0	0.0	0.0	0.3	0.6
scl	-	0.0	0.0	0.0	0.3	0.6
cl	-	0.0	0.0	0.0	0.3	0.6
sicl	-	0.0	0.0	0.0	0.3	0.6
sc	-	0.0	0.0	0.0	0.0	0.3
sic	-	0.0	0.0	0.0	0.0	0.3
c	-	0.0	0.0	0.0	0.0	0.3

MOUND DESIGN CONCEPTS

As with all soil based treatment/dispersal units, a mound system must be sized and configured to match the soil and site conditions and the volume and quality of wastewater applied to it. It is imperative that the designer has sufficient information about the quality and quantity of effluent, soil and site features and understands the mound operating principles and movement of effluent away from the system. The designer, in cooperation with the soil scientist or site evaluator, must accurately estimate the design basal loading rate (Table 2), determine the direction of flow away from the system (Figure 2) and estimate the linear loading rate, before the mound can be designed.

The design consists of estimating the 1) sand media loading rate, 2) basal (soil) loading rate and 3) linear loading rate for the site. Once these three design rates are determined, the mound can be sized for the site. Figure 4 shows a cross section and plan view of the mound on a sloping site and shows dimensions that must be determined.

Sand Media Loading Rate:

The design sand loading rate for the absorption area (aggregate/sand interface or chamber bottom/sand interface) is dependent upon the quality of the effluent applied and the type and quality of the fill material. This design assumes that the effluent quality is septic tank effluent from domestic wastewater. If high strength wastes from commercial establishments is the
source, such as from restaurants, the loading rates must be adjusted based on wastewater strength with comparable organic loading rates (BOD, TSS, FOG) (Siegrist et al., 1985) resulting in lower loading rates or the wastewater pretreated equal to or less than typical domestic septic tank effluent quality. If highly pretreated effluent (BOD and TSS < 25 mg/L and very low FOG) is used the loading rate of 2.0 gpd/ft^2 is reasonable. Separation distances may be reduced depending upon the fecal coliform count of the effluent (Converse and Tyler, 1998).

The purpose of the sand fill, along with the native soil, is to treat the effluent to an acceptable level. A very coarse sand will not provide adequate treatment and it may not be practical to use a median to fine sand because of the very low loading rate required to minimize clogging. Thus, the sand must be selected that provides satisfactory treatment and allows for a reasonable loading rate.

During the initial development of the mound, medium sand (USDA classification) was considered suitable for mound fill but it was soon shown that premature clogging resulted for sand fill that was on the fine side of medium. Bank run sand, which was classified as medium sand, was also found unsuitable, in most cases, as it was usually poorly sorted (high uniformity coefficient) and contained a lot of fines. Currently, **the recommendation is to use a coarse sand with a minimum amount of fines (<5%)** which appears to give acceptable treatment at an acceptable loading rate and reasonable cost. Standard classifications, such as USDA, are not suitable as they are very broad. For example, a sand classified as coarse sand may or may not be acceptable while a sand classified as medium sand may be as it depends upon a combination of various sand fractions.

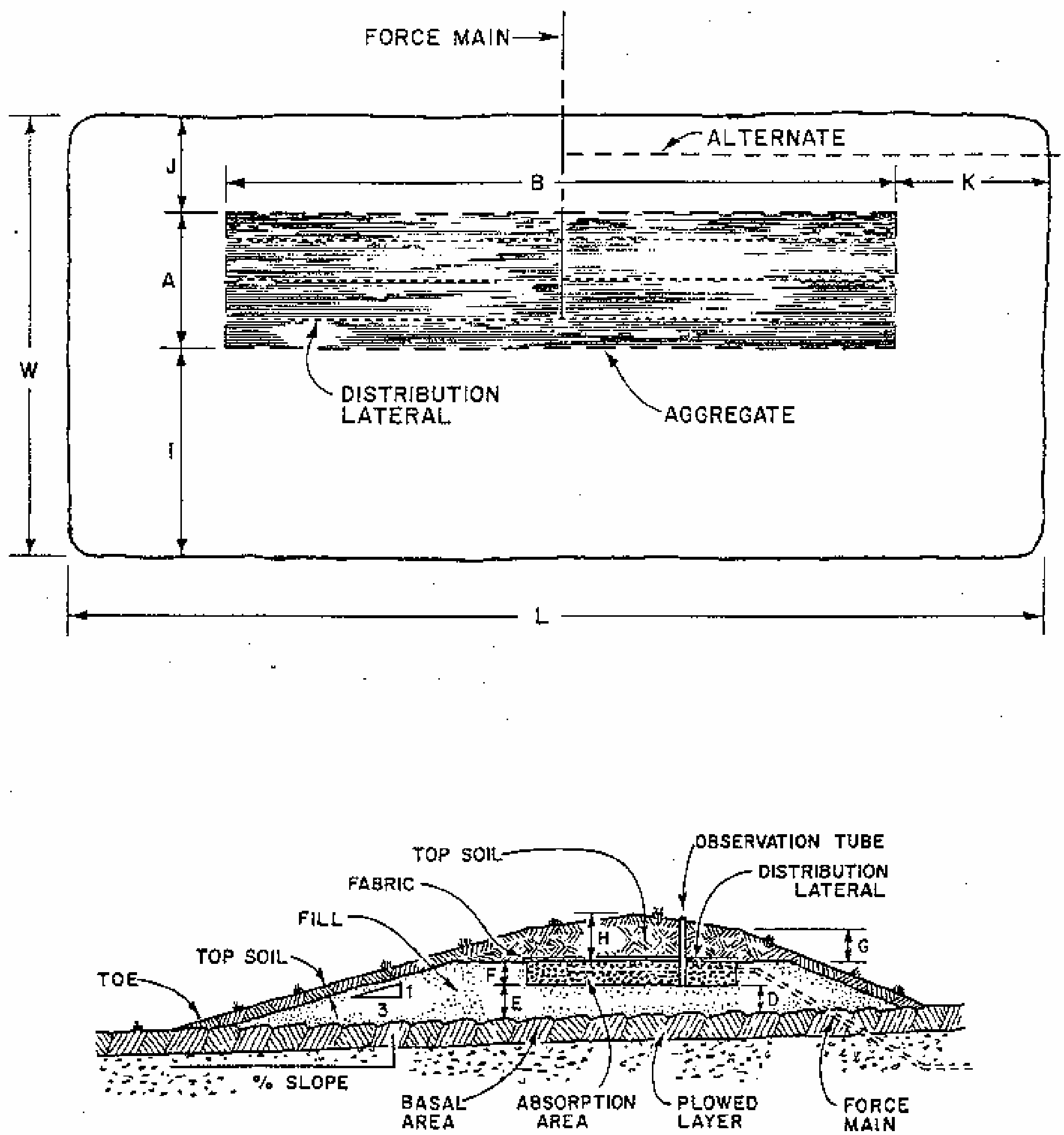

Fig. 4. Cross section and plain view of a mound system on a sloping site.

Figure 5 can be used as a guide for selecting a suitable mound sand fill. Based on a sieve analysis of the total sample, the sand fill specification should fit between the ranges given in Fig. 5. In addition, the sand fill must not have more that 20% (by wt) material that is greater than 2 mm in diameter (course fragments), which includes stone, cobbles and gravel. Also, there must not be more than 5% silt and clay (<0.53 mm, 270 mesh sieve) in the fill. **Less would be better.** C-33 specification (ASTM, 1984) for fine aggregate does fit within this guideline but the coarser (>2 mm) and finer (<0.53 mm) fractions must be evaluated to make sure they meet the limits. A sand with an effective diameter (D_{10}) of 0.15 – 0.30 mm uniformity coefficient (D_{60}/D_{10}) between 4 and 6 fit within these guidelines provided the coarser (>2 mm) and finer (0.053 mm) fractions meet the guideline. **Although these guidelines give a range, it is best to stay on the coarse side (left curve with effective diameter close to 0.30 mm and uniformity coefficient of 4.0) than to be on the fine side (near the right curve).** The single pass sand filter recommends a coarser sand with less fine material with effective diameter of 0.30 mm and uniformity coefficient of <4.0 and 0-2% passing the 100 mesh sieve and 0-1% passing the 200 mesh sieve (Orenco, 1998). Since the mound is a sand filter, the material recommended for sand filters would be suitable. The recommended sand filter loading rate is slightly higher than for mounds. The sand filter utilizes timed dosing with small frequent doses and less area/orifice, which enhances treatment quality, instead of demand dosing with large infrequent dosing.

The recommended design loading rate for a sand fill that meets the mound sand fill specification (Fig. 5) is 1.0 gpd/ft^2 for typical domestic septic tank effluent. Some designers may feel more comfortable using a design loading rate of 0.8 gpd/ft^2. Experience has shown that a clogging mat may form at this interface and lead to back up or breakout of septic tank effluent requiring corrective action. Based on many years of experience, some mounds have failed via clogging. Initial design called for a loading rate of 1.2 gpd/ ft^2. Reducing the sand loading rate does not substantially increase construction costs.

The 1.0 gpd/ft^2 loading rate assumes that there is a safety factor. It assumes, for design purposes, that a home generates 75 gpcd with two people per bedroom or 150 gallons per bedroom per day with the actual flow in the range of 50 to 60% of design. Converse and Tyler (1987) found, based on water meter readings in the home, that the wastewater generated averaged 47% of design with a range of 29 to 82%. However, some designers like to use the flow generated based on water meter readings or use the number of people per house times the estimated average of 50 gpd/c for design purposes. **If this approach is used, then a factor of safety of 1.5 to 2 must be incorporated or the design loading rate in gpd/ft^2 reduced accordingly.** Similar procedures should be followed for commercial establishments including lower loading rates due to the higher strengths effluents as discussed previously.

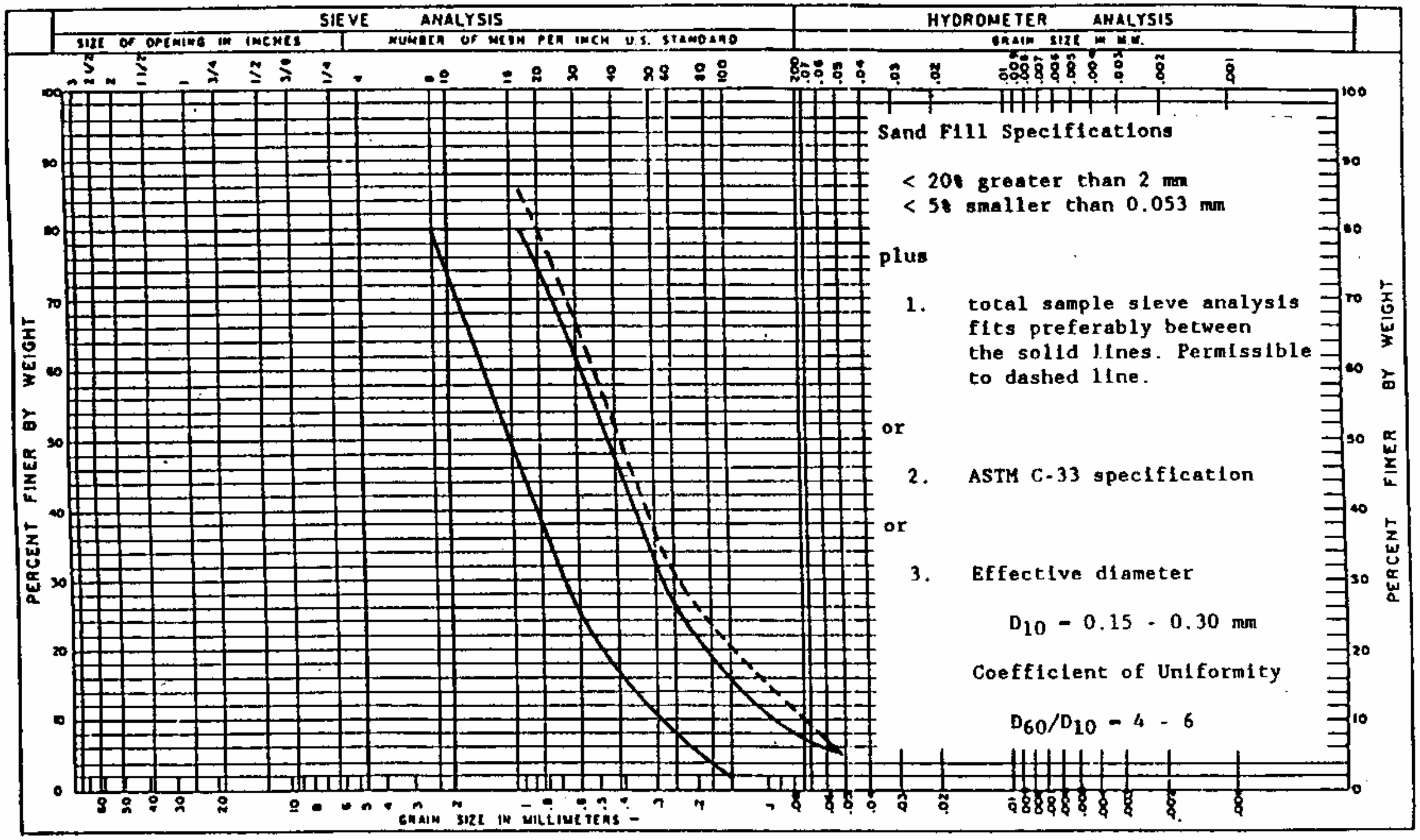

Figure 5. A guideline for the selection of the sand fill for Wisconsin Mounds. The total sample sieve analysis contains 20% or less material larger than 2.0 mm and contains 5% or less material finer than 0.053 mm plus one of the three additional specifications listed in figure. The fraction greater than 2 mm can have stones and cobbles.

Basal Loading Rate:

The basal area (sand/soil interface in Fig. 4) is the area enclosed by B(A+I) for sloping sites and B(A+I+J) for level sites where J = I for level sites. In the past basal loading rates assumed a clogging mat would form. Experience has shown that the clogging mat will not form at this interface because most of the organic matter (BOD and TSS) have been removed as it passes through the sand. Thus, the basal loading rate (gpd/ft^2) be higher than for septic tank effluent. Table 2 provides basal loading rates for septic tank effluent after having passed through the mound sand. These values assigned to the basal loading rate (BOD and TSS <30 mg/L) should be used with some caution because there is limited experience. Also the basal dimensions (I) calculated by these numbers is usually less than the value calculated for the side slope (3:1) except in very slowly permeable soils.

Hydraulic Linear Loading Rate:

The hydraulic linear loading rate is the volume of effluent (gallons) applied per day per linear foot of the system along the natural contour (gpd/ft). The design hydraulic linear loading rate is a function of effluent movement rate away from the system and the direction of movement away from the system (horizontal, vertical or combination, Fig. 2). If the movement is primarily vertical (Fig. 2a), then the hydraulic linear loading rate is not critical. If the movement is primarily horizontal (Fig. 2d), the hydraulic linear loading rate is extremely important. Figure 6 illustrates the effect of hydraulic liner loading rate on the configuration selected. Other factors such as gas transfer beneath the absorption area suggest that the absorption area width be relatively narrow regardless of the hydraulic linear loading rate(Tyler et al., 1986).

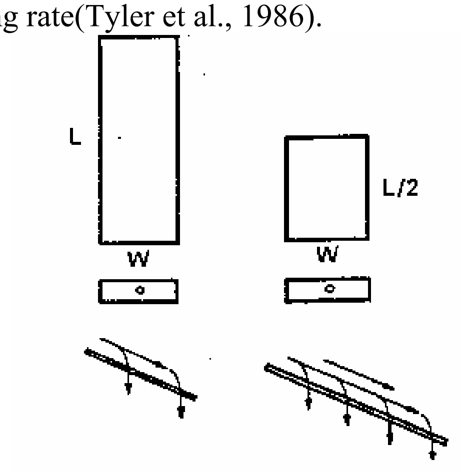

Fig. 6. The effect of linear loading rate based on system configuration on a sloping site. The sand or soil loading rates (gpd/ft2) are the same but the linear loading rate for the right figure is twice that of the left figure. The soil may not be able to move the effluent away from the system fast enough resulting in back up and breakout at the mound toe. This is more critical as mounds are placed on more difficult sites (shallow seasonal saturation and slowly permeable soils).

It is somewhat difficult to estimate the hydraulic linear loading rate for a variety of soil and flow conditions but based on the authors' experience "good estimates" can be given. If the flow is primarily vertical (Fig. 2a), then the hydraulic linear loading rate can be high but the gaseous linear loading rate (oxygen transfer to meet the oxygen demand) should be limited to 8-10 gpd/ft of typical domestic septic tank effluent. The slower the gas transport or the higher the wastewater BOD, the narrow the absorption area needed in order to meet the oxygen demand beneath the absorption area. If the flow is primarily horizontal, because of a shallow restrictive layer or limiting condition such as seasonal saturation or bedrock (Fig. 2d), then the linear loading rate should be in the range of 3-4 gpd/ft, resulting in long and narrow systems. Converse (1998) gives a more detailed explanation and provides two examples of estimating linear loading rate.

Sizing the Mound:

Figure 4 shows the cross section and plan view of the mound for sloping site. The dimensions are based on the site conditions and loading rates which are site specific. Prior
to designing, the designer needs to determine the following loading rates:

Design Flow Rate – gpd
Sand loading rate – gpd/ft^2
Basal Loading rate – gpd/ft^2
Hydraulic linear loading rate – gpd/ft

Absorption Area Width (A): The width of the absorption area is a function of the hydraulic linear loading rate and the design sand loading rate.

A = (Hydraulic Linear Loading Rate / Sand Loading Rate) = (gpd/ft) / (gpd/ft2)
= ft

Note: If the designer doesn't feel comfortable with using linear loading rate, he/she can select a width. It is recommended that width be less than 10 ft which may be to wide for some sites. Selecting a width, in essence, is selecting a linear loading rate. If the sand loading rate is 1.0 gpd/ft2 then the linear loading rate and width values are the same.

Absorption Area Length (B): The length of the absorption area, along the natural surface contour, is a function of the design flow rate (gpd) and the linear loading rate (gpd/lf).

B=(Design Flow Rate/Hydraulic Linear Loading Rate)=(gpd)/(gpd/ft)=ft

Basal Length (B) and Width (I, A and J): The basal length is (B) and the basal width for sloping sites is (I+A) and for level sites it is (I+A+J). The width is based on the linear loading rate and the basal loading rate for highly pretreated effluent (Table2).

For sloping sites:

I+A = (Hydraulic Linear Loading Rate/Basal Loading Rate)=(gpd/ft)(gpd/ft^2)=ft

For level sites:

I+A+J = (Hydraulic Linear Loading Rate/Basal Loading Rate)=(gpd/ft)(gpd/ft^2)=ft

Slope Widths (I and J): For sloping sites the down slope width (I) is a function of the mound depth at the down slope edge of the absorption area, desired side slope, normally 3:1 and the down slope correction factor. Up slope width (J) is a function of the mound depth at the up slope edge of the absorption area, the desired side slope, normally 3:1 and up slope correction factor. For level sites the slope widths (I) and (J) are equal and a function of the mound depth at the edge of the absorption area and the desired side slope, normally 3:1.

Slope Length (K): The slope length (K) is a function of the mound depth at the center of the absorption area and the desired mound end slope, normally 3:1. Steep end and side slopes are not recommended if the mound is to be mowed due to safety consideration. Typical dimensions are 8-12 ft.

Depth D: The depth of the sand fill is a function of the suitable soil separation depth required by code and the depth of the limiting condition from the soil surface. If the required separation distance from the absorption surface to the limiting condition, such as bedrock or seasonal saturation, is 3 ft and the limiting condition is 1 ft beneath the ground surface, then (D) must be a minimum of 2 ft which is measured at the up slope edge of the absorption area.

Depth E: This depth is a function of the surface slope and width of the absorption area (A) as the absorption area must be level.

Depth F: This depth is at least 9 in. with a minimum of 6 in. of aggregate beneath the distribution pipes, approximately 2" for the distribution pipe and 1" of aggregate over the pipe.

Depth G and H: The recommended depth for (G) and (H) for the soil cover is 6" and 12", respectively. The (H) depth is greater than the (G) depth to provide a crown to promote runoff from the mound top. For narrow absorption areas, 6" of difference is not required. Depths in earlier mound versions were 12 and 18" for cold climates. **Shallower depths are being recommended to allow for more oxygen diffusion to the absorption area.**

Mound Cover: The purpose of the mound soil cover is to provide a medium for a vegetative cover and protection. Any soil cover that will support a suitable vegetative cover and allow the mound to breathe is satisfactory. **It is important that the mound be able to breathe to allow oxygen to diffuse into and below the absorption area.** Clay loam, silty clay loam and clay soils restricts oxygen diffusion. Thicker soil covers also reduce oxygen transfer. The recommended mound cover consists of the sandy loam, loamy sands and silt loams. These coarser soils will not shed the precipitation as well as heavier soils and will not hold as much moisture during the summer dry periods but the benefits of breathing is probably superior to the negatives. If the soil cover does not support good vegetative cover, other means, such as decorative stone, must be implemented to avoid surface erosion.

Observation Tubes: It is essential that all soil absorption systems, including mounds, have observation tubes extending from the infiltrative surface (aggregate/sand interface for mounds) to or above the ground surface to observe ponding at the infiltrative surface. Tubes should be placed at approximately 1/4 and 3/4 points along the length of the absorption area. Fig. 7 illustrates three methods of anchoring the observation tubes. **The bottom 4" must have perforations in the sides to allow ponded effluent to enter and exit the pipes. Ponded effluent will not enter from the bottom of the pipe.**

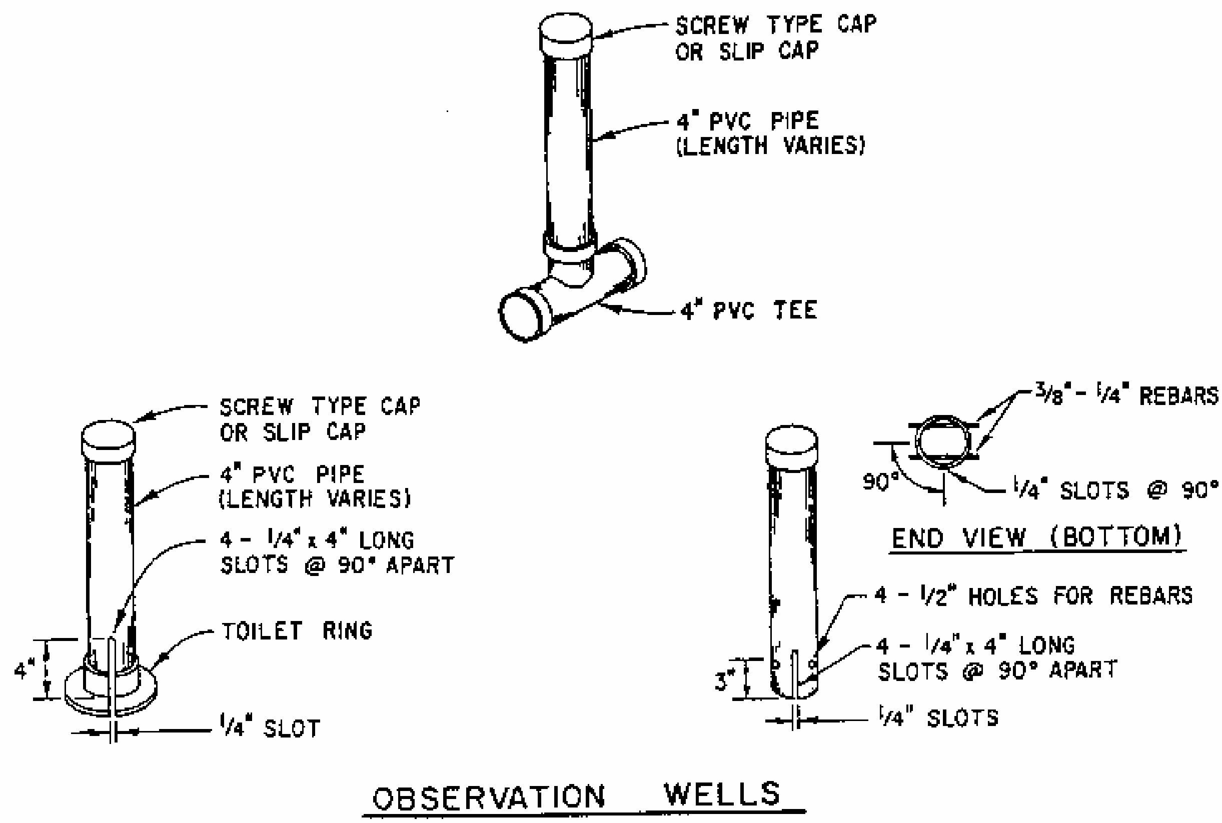

Fig. 7. Three methods of securing observation tubes.

Effluent Distribution Network: Pressure distribution network is essential for distributing the septic tank effluent. Gravity flow is unacceptable as it will not distribute the effluent uniformly over the infiltrative surface or along the length of the mound (Converse, 1974, Machmeier and Anderson, 1988). Otis (1981) provides design criteria and examples for pressure distribution. Converse (2000) discusses pressure distribution and provides a design example for the new criteria.

DESIGN EXAMPLE

Design an on-site system based on the following soil profile description.

Site Criteria

1. Soil Profile – Summary of 3 soil pits evaluations.

   A. 0 – 6 in. 10YR6/4&2/1; silt loam (Sil); strong, moderate, angular blocky structure; friable consistence.

   E. 6 – 11 in. 10YR5/3; silt loam (Sil); moderate, fine platy structure; firm consistence.

   B. 11-20 in. 10YR6/3; silty clay loam (Sicl); moderate, fine, subangular blocky structure; firm consistence, few, medium, distinct mottles starting at 11".

   C. 20-36 in. 10YR5/3; silty clay (sic); massive structure; very firm consistence; many, medium, prominent mottles.

2. Slope 20%

3. The area available consists of 170 ft along the contour and 50 ft along the slope. There are 3 medium size trees in the area.

4. The establishment generates 300 gallons of wastewater of domestic septic tank effluent per day based on water meter readings.

Step 1. Evaluate the quantity and quality of the wastewater generated.

For all on-site systems a careful evaluation must be done on the quantity of wastewater generated. As indicated earlier, most code values have a factor of safety built into the flows generated daily. These are the values that are typically used for design. It is appropriate for the designer to assess if the code value is appropriate for the given facility and if not, work with the regulators on a suitable number. If metered values are used, a suitable factor of safety must be added to the daily average flow such as 50 to

100%. The average flow should be based on a realistic period of time and not be, for example, an average of six months of very low daily flow rates and 6 months of very high flow rates in which case then the high flow rates should be used for design plus the factor of safety. **It is best to over design rather than under design even though the cost is greater but system performance and longevity should be greater.**

Effluent quality must also be assessed. If it is typical domestic septic tank effluent, these sizing criteria may be used. If it is commercial septic tank effluent, lower loading rates (gpd/ft^2) must be used (Siegrist, et al., 1985) or the effluent pretreated to acceptable BOD and TSS. Use a factor of safety of 150%.

Design Flow Rate = 300 gpd X 1.5 = 450 gpd.

Typical design flows are 150 gpd/bedroom.

(Experience has shown that some mounds designed at 150 gpd/bedroom have ponded even though the actual flow was probably well below the design).

Step 2. Evaluate the soil profile and site description for design linear loading rate and soil loading rate.

For this example and convenience the one soil profile description is representative of the site. A minimum of 3 evaluations must be done on the site. More may be required depending on the variability of the soil. The soil evaluator must do as many borings as required to assure that the evaluation is representative of the site. Soil pits are better than borings but a combination are satisfactory. In evaluating this soil profile, the following comments can be made:

The silt loam (A) horizon (0-6”) is relatively permeable because of its texture, structure and consistence. The effluent flow through this horizon should be primarily vertical.

The silt loam (E) horizon (6-11”) have a platy structure and firm consistence. The consistence will slow the flow and the platy structure will impede vertical flow and cause the flow to move horizontally. If this layer it tilled, the platy structure will be rearranged and the flow will be primarily vertical. **Thus, tillage must be done at least 11 in. deep on this site to rearrange the platy structure.** It the structure in this horizon was not platy, then tillage would be limited to 5-6” in-depth.

The silty clay loam (B) horizon (11-20 in.) is slowly permeable because of the texture and firm consistence. The flow will be a combination of vertical and horizontal flow in the upper portion and primarily horizontal flow in the lower portion of the horizon due to the nature of the next lower horizon. During wet weather the "B" horizon may be saturated with all flow moving horizontally.

The silty clay (C) horizon (20 - 36 in.) will accept some vertical flow as the effluent moves horizontally down slope in the upper horizons. The flow through this profile will be similar to the cross section shown in Fig. 2c and during seasonal saturation as shown in Fig.2b.

Based on experience a properly designed mound system should function on this site. It meets the minimum site recommendations found in Table 1.

Linear loading rates range from about 1 – 10 gpd/lf. Since this site has a very shallow seasonal saturation and a very slowly permeable horizon at about 20", and seasonal saturation at 11", the linear loading value for this site should be 3-4 gpd/lf.

Linear Loading Rate = 4 gpd/lf

Note: LLR = 3 could be used for a more conservative design and less risk of toe leakage especially during seasonal saturation.

A basal loading rate for the soil horizon in contact with the sand (basal area) is selected based on the surface horizon (A). Use table 2 to determine the design basal loading rate.

Basal Loading Rate = 0.8 gpd/ft^2

Step 3. Select the sand fill loading rate.

The section entitled "Sand Fill Loading Rate" and Fig. 6 give guidelines for selecting a suitable sand fill for the mound. Other fills may be used but caution should be used as performance data is very limited with the other fills.

Sand Loading Rate = 1.0 gpd/ft^2

No absorption area credit is given for use of chambers in mounds.

Step 4. Determine the absorption area width (A).

A = Linear Loading Rate / Sand Loading Rate

= 4 gpd/ft / 1.0 gpd/ft^2
= 4 ft (Since this appears to be the weak point in the mound, consider making it 6 ft wide. A 6 ft wide absorption area would give a sand loading rate of 0.67 gpd/gpd/ft^2. The linear loading rate will

remain at 4 gpd/lf. However, increasing the area will require more orifices in the pressure distribution network).

Step 5. Determine the absorption area length (B).

B = Design Flow Rate /Linear Loading Rate

= 450 gpd / 4 gpd/lf
= 113 ft.

Step 6. Determine the basal width (A + I).

The basal area required to absorb the effluent into the natural soil is based on the soil at the sand/soil interface and not on the lower horizons in the profile. An assessment of the lower horizons was done in Step 2 when the linear loading rate was estimated.

A + I = Linear Loading Rate / Basal Loading Rate

= 4 gpd/ft / 0.8 gpd/ft^2
= 5.0 ft (The effluent should be absorbed into the native soil, within a 5 ft.)

Since A=4 ft

I + 5.0' – 4.0' = 1 ft ("I" will also be calculated based on side slope)

Step 7. Determine the mound fill depth (D).

Assuming the code requires 3 ft of suitable soil and soil profile indicates 11 in. of suitable soil then:

D= 36" – 11" = 25 in.

Step 8. Determine mound fill depth (E).

For a 20% slope with the bottom of the absorption area level then:

E = D + 0.20(A)
= 25" + 0.20 (48")
= 35 in.

Step 9. Determine mound depths (F), (G) and (H)

F = 9 in. (6 in. of aggregate, 2 in. for pipe and 1 in. for aggregate cover over pipe) G = 6 in. H = 12 in.

These depths have changed form 12 and 18” so as to allow more oxygen to diffuse into and beneath the absorption area. Sand filters have only 6” of cover and freezing is not a problem as long as the distribution network drains after each dose. Granted most sand filters are below grade which may be a factor.

Step 10. Determine the up slope width (J)

Using the recommended mound side slope of 3:1 then:

J = 3 (D + F + G) (Slope Correction Factor from Table 3)

= 3 (25” + 9” + 6”) (0.625)
= 6.25 ft or 6 ft

Step 11. Determine the end slope length (K).

Using the recommend mound end slope of 3:1 then:

K = 3 ((D + E)/2 + F + H)

= 3 ((25” + 35”)/2 + 9” + 12”)
= 12.75 ft or 13 ft

Step 12. Determine the down slope width (I)

Using the recommended mound side slope of 3:1 then:

I = 3 (E + F + G) (Slope Correction Factor from Table 3)
= 3 (35” + 9” + 6”) (2.5)
= 37.5 ft.

Since the I dimension becomes quite large on steeper slopes, it may be desirable to make the down slope steeper such as 2:1 and not mow the mound. If the natural slope is 6% instead of 20% the mound width would be 28 ft (9 + 4 + 15).

Step 13. Overall length and width (L + W)

L = B + 2K

= 113 + 2(13)
= 139 ft
W = I + A + J
= 31 + 4 + 6
= 41 ft

Step 14. Design a Pressure Distribution Network

A pressure distribution network, including the distribution piping, dosing chamber and pump, must be designed. A design example is presented by Converse, 2000. Items to consider when designing the pressure distribution network.

- Using 3/16” holes instead of 1/4” holes with an effluent filter in the tank.

- Using 6 ft^2/orifice instead of the typical 15 – 20 ft^2/orifice that has been used.

- Provide easy access to flush the laterals such as turn-ups at end of laterals.

- Dose volume at 5 times the lateral pipe volume and not to exceed 20% of the design flow and not dose at the previously recommended 1/4 the design flow or 10 times the lateral void volume.

- Timed dosing which requires surge capacity in the septic tank/pump chamber. With the configuration of the mound (long and narrow), the dose volume is larger than for sand filter and time dosing may be not be appropriate if larger dose volumes are required due to 5 times the lateral volume.

MOUND PERFORMANCE

The first Wisconsin mound system of the current design was installed in 1973. In Wisconsin there are over 30,000 mounds based on estimates by state regulators. Many other states have adopted the technology. Proper siting of all soils absorption units, including the mound, is essential otherwise the system will not function as planned.

In Wisconsin the mound system has a success rate of over 95% based on a survey by Converse and Tyler (1986b). This success rate is due in part to a very strong educational program relating to siting, design and construction.

A mound can fail either at the 1) aggregate or chamber/sand interface due to a clogging mat, 2) at the sand/soil interface due to the inability of the soil to accept the influent or 3) plugging of the pressure distribution network. Converse and Tyler (1989) discuss the mechanism that may cause failure and methods to rectify the problem. Another alternative (not discussed in that publication) to renovate mounds, that have severe ponding, is to introduce highly pretreated

Table 4. Down slope and up slope correction factors

Slope %	Down Slope Correction Factor	Up Slope Correction Factor
0	1.00	1.0
1	1.03	0.97
2	1.06	0.94
3	1.10	0.92
4	1.14	0.89
5	1.18	0.88
6	1.22	0.85
7	1.27	0.83
8	1.32	0.80
9	1.38	0.79
10	1.44	0.77
11	1.51	0.75
12	1.57	0.73
13	1.64	0.72
14	1.72	0.71
15	1.82	0.69
16	1.92	0.68
17	2.04	0.66
18	2.17	0.65
19	2.33	0.64
20	2.50	0.62
21	2.70	0.61
22	2.94	0.60
23	3.23	0.59
24	3.57	0.58
25	4.00	0.57

effluent to the mound by installing an aerobic unit, Nibbler Jr (NCS, 1998) or equivalent between the septic tank and pump chamber (Converse et al., 1998).

Converse et al., (1994) evaluated 13 mound systems for performance based on fecal coliform movement, nitrogen and chloride movement beneath the mound. Some fecals were found outside the 3 ft treatment zone beneath the system. The cause, though not definitive, may be related to the large infrequent doses of septic tank effluent to the mound which is typical of demand dosing and the large orifice spacing (15 to 20 ft^2).

MOUND CONSTRUCTION

A construction plan for any on-site system is essential. A clear understanding between the site evaluator, the designer, contractor and inspector is critical if a successful system is installed. It is important that the contractor and inspector understand the principles of operation of the mound system before construction commences otherwise the system will not function as intended. It is also important to anticipate and plan for the weather. It is best to be able to complete the mound before it rains on it. The tilled area (basal area) and the absorption area must be protected from rain by placing sand on the tilled area and aggregate on the absorption area prior to precipitation. There are several different ways to construct a mound as long as the basic principles and concepts are not violated. The following are suggested construction steps:

1. The mound must be placed on the contour. Measure the average ground surface elevation prior to tillage along the up slope edge of the absorption area. This contour will serve as the base line for determining the elevation of the bottom of the absorption area.

2. Grass, shrubs and trees must be cut close to the ground surface and removed from the site. In wooded areas with excess litter, it is recommended to rake the majority of it from the site. Do not pull out the stumps and do not remove the sod or the top soil or boulders.

3. Determine where the force main from the pump chamber enters the mound. It will either be center feed or end feed. For long mounds, center feed is preferred and all end feeds can be made into center feed. For center feed the force main can enter from the up slope center (preferred), the down slope center or exit the native soil at the end and be placed horizontally on a slight slope in the sand beneath the aggregate or just up slope of the aggregate. It must be brought in from the down slope side, especially on slowly permeable soils with high seasonal saturation where the effluent flow may be horizontal, it should be brought in perpendicular to the side of the mound with minimal disturbance to the down slope area. All vehicular traffic must be kept in a very narrow corridor. Minimal damage is done if the soil is dry. Soil should be packed around the pipe and anti-seep collars should be installed to minimize effluent and water following the pipe. Entering from the down slope center should be the last choice on sites that are slowly permeable with shallow seasonal saturation.

4. The footprint of the mound must be tilled only when the soil moisture is within a satisfactory range. The satisfactory moisture range, to a depth of 6-7", is defined as where the soil will crumble and not form a wire when rolled between the palms. The purpose of tillage is to roughen the surface to allow better infiltration into the top soil. It also provides more contact between the sand and the soil. Excessive tillage will destroy soil structure and reduce infiltration. The preferred method is using chisel teeth mounted on a backhoe which can be easily removed, followed by a chisel plow pulled behind a tractor, followed by the backhoe bucket with short teeth which requires flipping the soil. Normally it takes much longer to use the backhoe bucket than a chisel teeth mounted on

the backhoe with the added cost quickly recovered. Moldboard plows have been used successfully but are the least preferred.

Rototillers are prohibited on structured soils but may be used on unstructured soils such as sand to break up the vegetation. However, they are not recommended. All tilling must be done following the contour.

If a platy structure is present in the upper horizons, the tillage depth should be deep enough to try to break it up without bringing an excessive amount of subsoil to the surface. Deep tilling for the sake of deep tilling is not recommended. Till around the stumps without exposing an excessive amount of roots. Chisel teeth, mounded on a backhoe, is the preferred and an easier method for tilling around stumps. Stumps are not to be removed but some small ones may be inadvertently pulled out during tilling. If so, remove them from the site. If there are an excessive number of stumps and large boulders, the basal area should be enlarged or another site selected but that is the rare occasion.

5. Once the site has been tilled, a layer of sand must be placed before it rains. Driving on the exposed tilled soil is prohibited so as not to compact it or rut it up. Sand should be placed with a backhoe (preferred) or placed with a blade and track type tractor. A wheeled tractor will rut up the surface. **All work is to be done from the up slope side so as not to compact the down slope area especially if the effluent flow is horizontally away from the mound.**

6. Place the proper depth of sand, then form the absorption area with the bottom area raked level. The sand should be reasonably compacted in the trench area to minimize settling. A good backhoe operator can form the trench with minimal hand work.

7. Place a clean sound aggregate to the desired depth. **Limestone is not recommended**. If chambers are used, proper procedures must be performed to keep the chambers from settling into the sand. Procedures are available from the manufacturers that include compacting the sand to a certain specification and placing a coarse netting on the compacted surface prior to chamber placement.

8. Place the pressure distribution network with holes located downward and cover it with 1 in. of aggregate. Connect the force main to the distribution network. If chambers are used, the pressure distribution laterals must be suspended from the chambers with holes upward. Provisions must be made to allow the laterals to drain after dosing. This is accomplished by having several holes located downward or sloping the pipe in the chamber toward the force main. The laterals and force main must drain after each dose.

9. Cover the aggregate with a geotextile synthetic fabric.

10. Place suitable soil cover on the mound. There should be 6” on the sides and shoulder (G) and 12” on the top center (H) after settling. The soil cover should support vegetation. If not provisions must be made to control erosion.

11. Final grade the mound and area so surface water moves away from and does not accumulate on the up slope side of the mound. Use lightweight equipment.

12. Seed and mulch the entire exposed area to avoid erosion. Advise the homeowner on proper landscaping. The top of the mound becomes dry during the summer and the down slope toe may be wet during the wet seasons. Avoid deep rooted vegetation on the top of the mound to minimize root penetration into the distribution network (Schutt, K., et al. 1981)

13. Inform homeowner about the type of system, maintenance requirements and do’s and don’ts associated with on-site soil based systems.

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Here are some details of At-Grade systems and construction instructions for both At-Grade and Mound systems.

MOUND and AT-GRADE CONSTRUCTION INSTRUCTIONS

Only construct the system when the soil moisture is satisfactory. The satisfactory moisture range, to a depth of 7-8", is defined as where the soil will crumble and not form a wire when rolled between the palms

1. The mound must be placed on the contour. Measure the average ground surface elevation prior to tillage along the up slope edge of the absorption area. This contour will serve as the base line for determining the elevation of the bottom of the absorption area.

2. Grass, shrubs and trees must be cut close to the ground surface and removed from the site. In wooded areas with excess fitter, it is recommended to rake the majority of it from the site. Do not pull out the stumps and do not remove the sod or the topsoil.

3. Determine where the force main from the pump chamber enters the mound. It will either be an end feed or an center feed. For center feed the force main can enter from the up slope center, the down slope center or exit the native soil at the end and be placed horizontally on a slight slope-in the sand beneath the aggregate or just up slope of the aggregate, depending if it is a mound or at-grade. If it must be brought in from the down slope side, in perpendicular to the side of the mound with minimal disturbance to the down slope area. All vehicular traffic must be kept in a very narrow corridor. Minimal damage is done if the soil is dry. Soil should be packed around the pipe to minimize effluent and water following the pipe. Entering from the down slope center should be the last choice on sites that are slowly permeable with shallow seasonal saturation.

4. The footprint of the mound must be ripped only when the soil moisture in within a satisfactory range. The satisfactory moisture range, to a depth of 7-8", is defined as where the soil will crumble and not form a wire when rolled between the palms. The purpose of tillage is to roughen the surface to allow better infiltration into the topsoil. It also provides more contact between the sand and the soil. Excessive tillage will destroy soil structure and reduce infiltration. The preferred method is using chisel teeth mounted on a backhoe which can be easily remove, second choice is a chisel plow pulled behind a tractor, third choice is a mold board plow. Tilling along the contour is required.
Till around the stumps without exposing an excessive amount of roots. Chisel teeth mounted on a backhoe is the preferred and an easier method for tilling around stumps. Stumps are not to be removed but some small ones may be inadvertently pulled out during tilling. If so, remove them from the site. If there are an excessive number of stumps and large boulders, the basal area should be enlarged or another site selected.

5. AD work should be done from the up slope side so as not to compact the down slope area especially if the effluent flow is horizontally away from the mound.

(Numbers 6 & 7 do not apply to at-grade systems)

6. Driving on the exposed tilled soil is prohibited so as not to compact it or rut it up. Sand should be placed with a backhoe or placed with a blade and track type tractor. A wheeled tractor will rut up the surface. All work should be done from the up slope side so as not to compact the down slope area especially if the effluent flow is horizontally away from the mound.

7. Place the proper depth of sand then form the absorption area with the bottom area raked level. The sand should be reasonably compacted in the trench area to minimize settling. A good backhoe operator can form the trench with minimal handwork.

8. Place clean washed river gravel to the desired depth.

9. Place the pressure distribution network with holes located downward and cover it with 2 inches of aggregate. Connect the force main to the distribution network. If chambers are used, the pressure distribution laterals shall have holes pointing upward. Provisions must be made to allow the laterals to drain after dosing. This is accomplished by having several holes located downward or sloping the pipe in the chamber toward the force main. The laterals and force main must drain after each dose.

10. Cover the aggregate with a geotextile synthetic fabric.

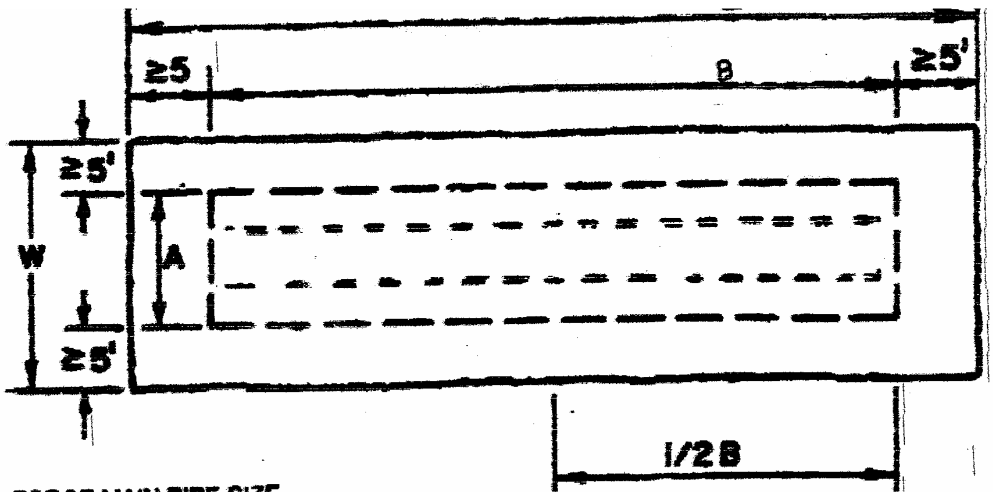
11. Place suitable soil cover on the mound. There should be 6" on the sides and shoulder (G) and 12" on the top center (H). The soil cover should support vegetation. If not provisions must be made to control erosion.

12. Final grade the mound and area so surface water moves away from the mound and does not accumulate on the up slope side of the mound. Use lightweight equipment.

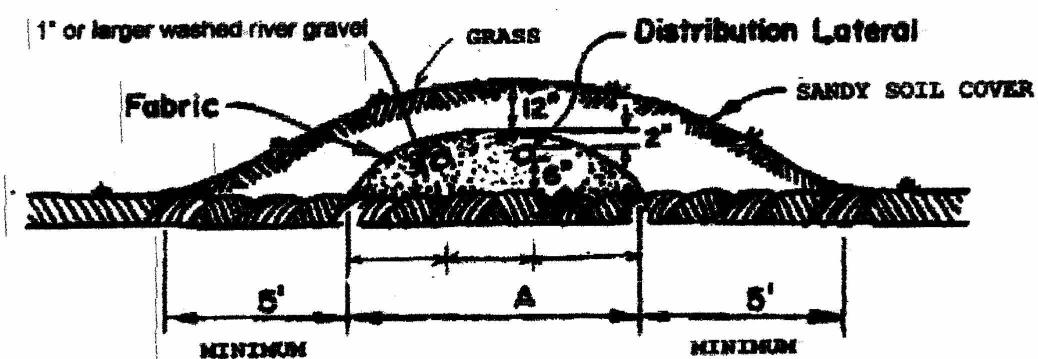
13. Seed and mulch the entire exposed area to avoid erosion. Advise the homeowner on proper landscaping. The top of the mound becomes dry during the summer and the down slope toe may be wet during the wet seasons. Avoid deep-rooted vegetation on the top of the mound to minimize root penetration into the distribution network.

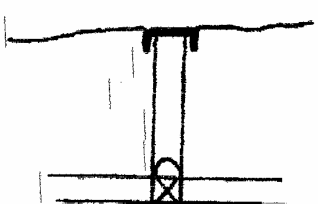
14. It is important to complete the mound system before it rains.

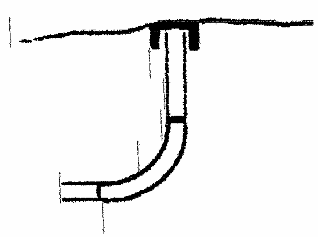
15. Inform homeowner about the type of system, maintenance requirements and do's and donts associated with on-site soil based systems.

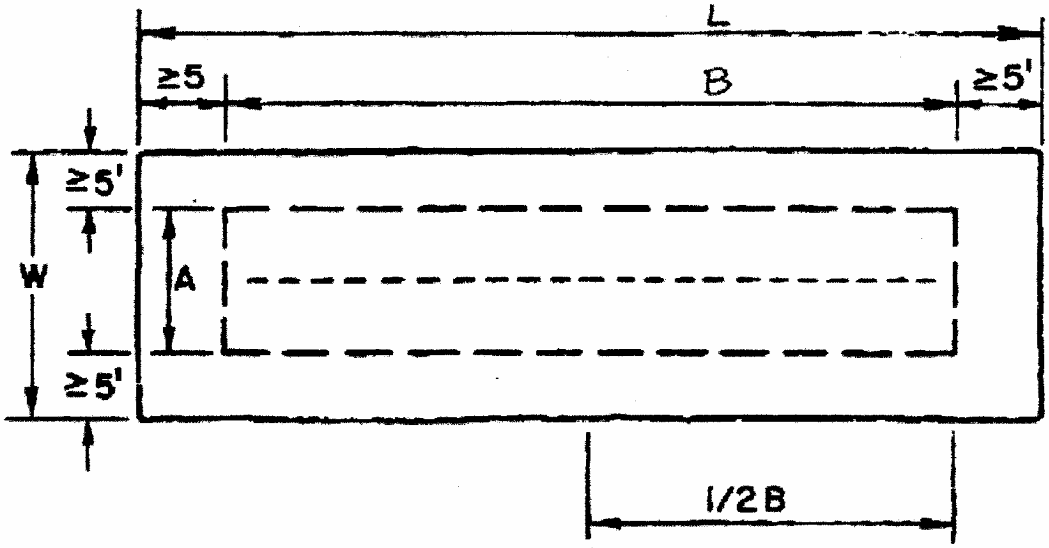


FORCE MAIN PIPE SIZE _____
DISTRIBUTION PIPE SIZE _____
WITH _______ INCH HOLES AT _______ INCHES ON-CENTER.
POINT HOLES DOWN, EXCEPT ONE HOLE POINTING UP
TO RELEASE AIR IN THE LINE.









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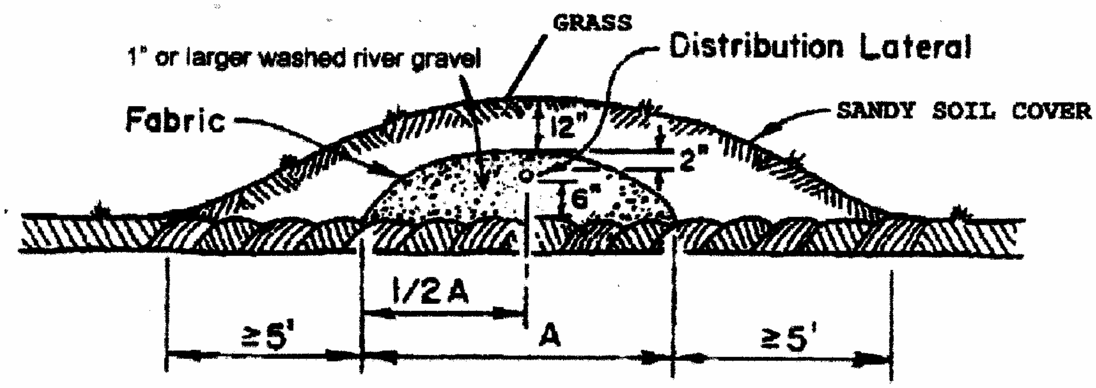
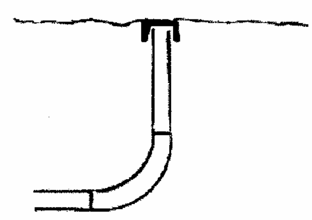




SECTION E: Above-Grade Systems

Contents

Figures

SECTION E: Above-Grade Systems

Part 1: At-Grade Systems

The at-grade system is an alternative to consider when you have exactly 3 feet to the water table, or when you have soils that you do not want to excavate (typically heavier soils).

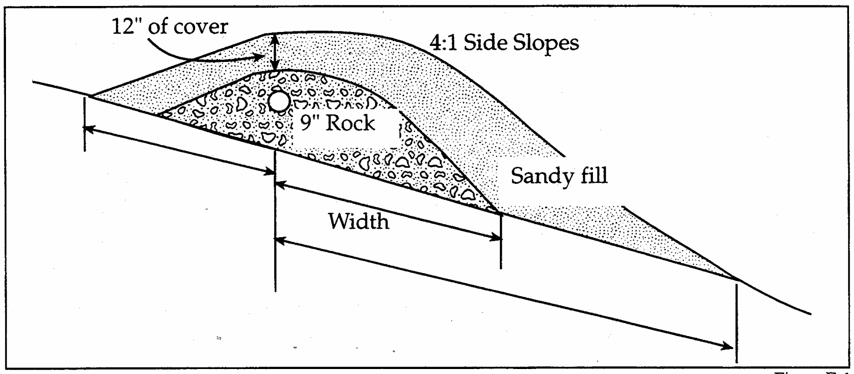


Figure E-1

This system cannot be used if the distance to the water table is less than 3 feet.

System Advantages

One of the advantages of using an at-grade system is the potential savings in material. The material used to cover the rock bed should be a sandy material, but it does not need to be the same clean sand used in the construction of a mound.

The other advantage of this system is that spreading it out across the slope (long and narrow) offers better potential treatment of nutrients and other contaminants found in the effluent. By maintaining a 3-foot separation to the water table, treatment and removal of the potential contaminants is all but guaranteed.

Basis for Design

The design of the at-grade system is based on flow, soil flow patterns as dictated by the linear loading rate (LLR) and the general geometry of a system built above ground. The flow is the same as that used in other design systems based on the necessary flow for a particular sized house.

Linear loading rate refers to potential horizontal and vertical flow patterns in the soil. These characteristics are based on soil texture, soil structure and limiting layers existing in the soil.

The range of the linear loading rate is from 2 to 8 gallons per foot. The 2-gallon-per-foot minimum dictates a near 100% horizontal flow of effluent. This minimum would be used for a system limited by impermeable bedrock or very heavy clay soils, or in any situation where horizontal movement of contaminants is a concern.

The 8-gallon-per-foot loading rate (the maximum) would be used when water moves down through the soil much faster than it moves sideways, as would be indicated by a consistent sandy soil profile.

A typical design number should be somewhere between these two. For a typical soil horizon made up of a variety of soil textures, a linear loading rate of 4 gallons per foot should be used.

MPI	**Soil Texture**	Other characteristics in the intail 48"	Linear Loading Rate (gpd/ft)
Faster than 0.1	Coarse Sand	For the entire depth	6
0.1 to 5	Sand	No Banding Layers with no Mottles Layers with Mottles	8 4 2
0.1 to 5 6 to 15	Fine Sand* Sandy Loam	No change in texture Layers of other textures	6 4
16 to 30 31 to 45 46 to 60	Loam Silt Loam Clay Loam	No change in texture Layers of other textures	4 3
60 to 120 Slower than 120	Clay Clay Bedrock	For the entire depth or encountered in boring	2

*Soils having 50% or more fine sand plus very fine sand

Figure E-2

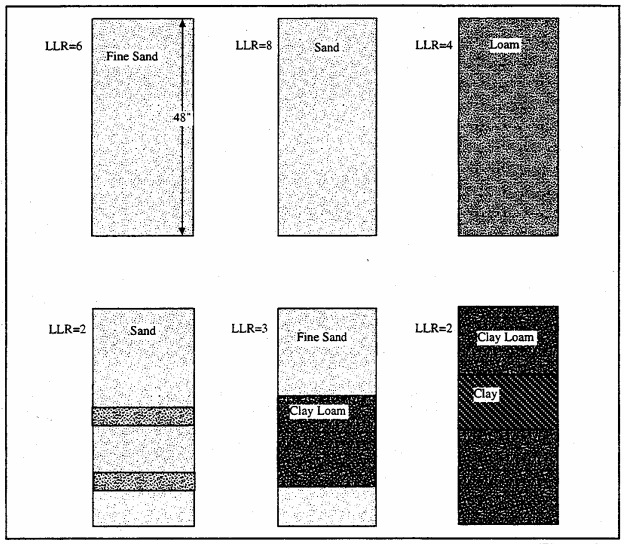


Figure E-3

Linear Loading Rate examples

Calculating System Size

Required system length is calculated by dividing daily flow by the linear loading rate. The linear loading rate is also used to size the width of the system. Since the width of the rock should encompass the absorption width of this system, multiply the linear loading rate by the soil absorption ratio to determine the proper size of the system. (This calculation is very similar to the absorption width calculation for a mound system.)

LLR used to calculate rock width & length

For example: For a 4-bedroom house over loam soil on an 8% slope, use a linear loading rate of 4.

- ❒ The length of the rock bed would be the flow (600) divided by the linear loading rate (5), or 120 feet.
- ❒ The width would be the linear loading rate (5) multiplied by the soil sizing factor (1.67), which equals 8 feet (8.35').

Thus, the rock bed would be 8 feet by 120 feet.

The final calculation is the requirement for the downslope width and the upslope width. This is done using a height of 2 feet and the slope multipliers given in Figure E-4.

BERM SLOPE MULTIPLIERS

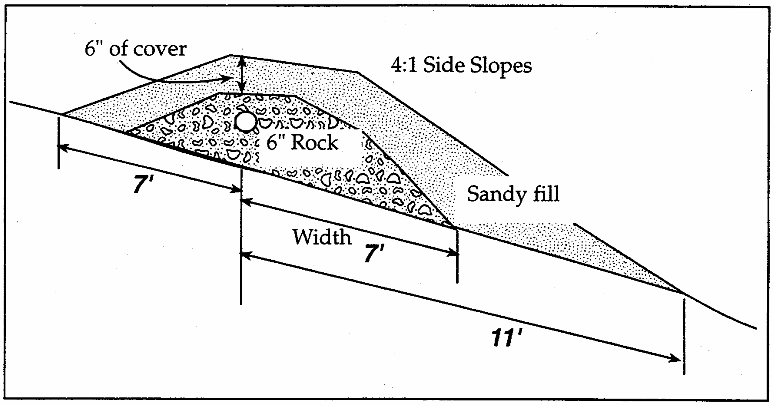
Land Slope, in %	DOWNSLOPE berm multipliers for various berm slope ratios					UPSLOPE berm multipliers for various berm slope ratios					
	3:1	4:1	5:1	6:1	7:1	3:1	4:1	5:1	6:1	7:1	8:1
0	3.0	4.0	5.0	6.0	7.0	3.0	4.0	5.0	6.0	7.0	8.0
1	3.09	4.17	5.26	6.38	7.53	2.91	3.85	4.76	5.66	6.54	7.41
2	3.19	4.35	5.56	6.82	8.14	2.83	3.70	4.54	5.36	6.14	6.90
3	3.30	4.54	5.88	7.32	8.86	2.75	3.57	4.35	5.08	5.79	6.45
4	3.41	4.76	6.25	7.89	9.72	2.68	3.45	4.17	4.84	5.46	6.06
5	3.53	5.00	6.67	8.57	10.77	2.61	3.33	4.00	4.62	5.19	5.71
6	3.66	5.26	7.14	9.38	12.07	2.54	3.23	3.85	4.41	4.93	5.41
7	3.80	5.56	7.69	10.34	13.73	2.48	3.12	3.70	4.23	4.70	5.13
8	3.95	5.88	8.33	11.54	15.91	2.42	3.03	3.57	4.05	4.49	4.88
9	4.11	6.25	9.09	13.04	18.92	2.36	2.94	3.45	3.90	4.30	4.65
10	4.29	6.67	10.00	15.00	23.33	2.31	2.86	3.33	3.75	4.12	4.44
11	4.48	7.14	11.11	17.65	30.43	2.26	2.78	3.23	3.61	3.95	4.26
12	4.69	7.69	12.50	21.43	43.75	2.21	2.70	3.12	3.49	3.80	4.08

Note: The product of the multiplier and the height results in the horizontal distance to where the berm meets the original land slope. Example: Height at upper edge of rock layer is 3.0 feet, rock layer is 10 feet wide, land slope is 6% and berm slope ratio is 4:1. Upslope berm width is 3.23 x 3.0 = 9.7 ft; height at lower edge of rock layer is 3.0 + 10 x 0.6 = 3.6 ft and downslope berm width is 5.26 x 3.6 = 18.9 ft.

Figure E-4

❒ Assuming a slope of 8 and a 4:1 slope, the upslope dimension would be the height (2) times the upslope multiplier (3.03), which would be an upslope berm of 7 feet.

❒ The downslope would be the height (2) times the downslope multiplier (5.33), which is a downslope of approximately 11'.
or
The rockbed plus 5' (8'+5'=13') whichever is greater. The downslopde width would be 13'.



Finished At-Grade System example

Figure E-5

Construction Procedures

Check out Mound Construction

Construction procedures for at-grade systems are similar to those for a mound system, with roughening of the soil followed by placement of the material. Extreme care should be taken in the area that has been roughened to minimize any effects to the soil.

At-grade systems should be constructed using pressure distribution. During testing of these systems, the only system failures that did occur happened when gravity distribution was used instead of pressure distribution.

Be careful when breaking to fit for a small lot

If the necessary length cannot be found on the slope in one continuous section, this system can be broken into smaller pieces using the same dimensions. Care should be given in the design of the pressure distribution system, since, if the laterals are at different elevations, the separation of the holes would have to be designed differently.

Part 2: Mound Systems

Mounds must be carefully constructed

A sewage treatment mound is a seepage bed elevated by clean sand fill to provide an adequate separation distance between the rock layer in the mound and the barrier layer such as saturated soil conditions or bedrock. The mound must be carefully constructed to provide adequate sewage treatment.

Mound failures have usually been traced to improper construction practices.

Important Design Factors

Important factors in the design and successful operation of a sewage treatment mound are:

- ❒ Location
- ❒ Size and shape
- ❒ Soil surface preparation
- ❒ Construction procedures
- ❒ Distribution of effluent
- ❒ Dosing quantity
- ❒ Quality of clean sand fill

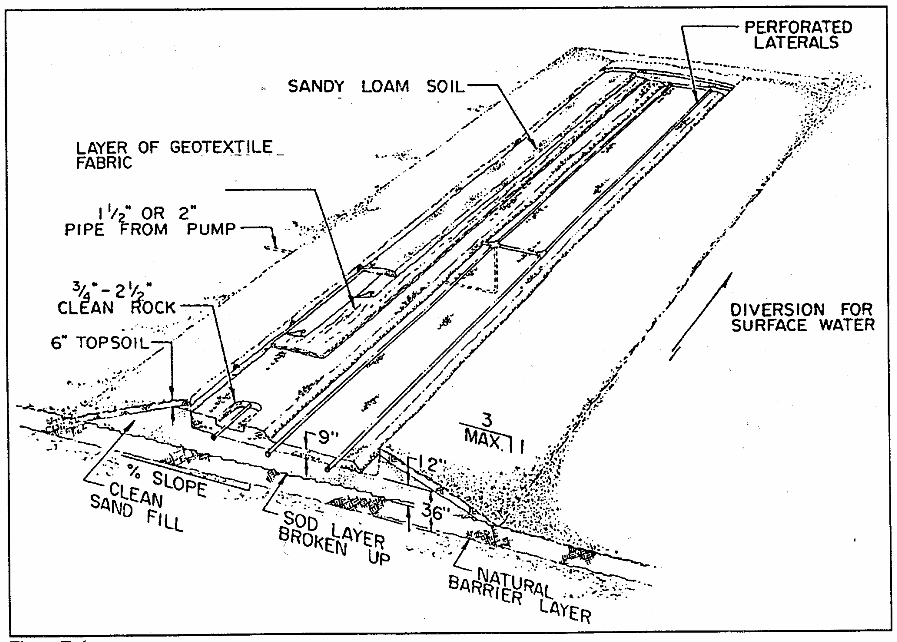


Figure E-6

Sewage Treatment Mounds for Problem Soils

Suitable soil provides excellent treatment of sewage tank effluent. The natural topsoil should be utilized for treatment wherever possible. The surface layer of a clay soil usually has a more rapid percolation rate than the underlying subsoil. Sandy soils have more organic matter in the top soil layer than in deeper layers. Soils with adequate organic matter and calcium carbonate (limestone) are good absorbers of the nutrient phosphorus found in sewage tank effluent.

Some soils do not have a percolation rate in the range of 0.1 to 60 minutes per inch (mpi), which is necessary for the proper operation of the soil treatment system. In other soils, there is seasonal saturation at depths closer than 3 feet to the ground surface, such that adequate vertical separation of the soil treatment unit is not possible under "natural" conditions. Soils with a "pan" layer, that restricts downward movement of liquid, or with fractured or permeable bedrock have problems for adequate treatment and acceptance of septic tank effluent.

Mounds Are Effective Sewage Treatment Methods

Properly designed and constructed sewage treatment mounds are an effective method of onsite sewage treatment. Research at the Small-Scale Waste Management Project indicates that residential mounds utilizing pressure distribution will have 44% fewer nitrates percolating downward than a standard subsurface trench system.

Nitrate removal up to 44%

Sufficient numbers of mounds have been installed in Minnesota and elsewhere to prove that the mound treatment system should be an accepted technology. There are more than 8,000 single-family mounds successfully treating sewage in Minnesota.

Minnesota has found that properly designed and constructed mounds are an effective method of sewage treatment and accept them as a standard system. Sewage treatment mounds should not be considered alternative treatment systems but rather preferred treatment systems, in many instances.

What Mounds Look Like

Figures E-6, E-7 and E-8 show three different perspectives of mound design. FigureE-7 is a cross-sectional view and E-8 is a plan view of a mound system. Mound construction begins with the layer of clean

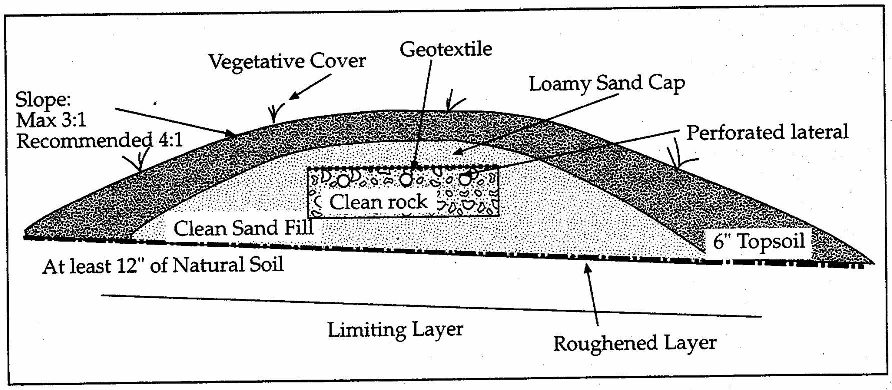


Figure E-7

sand which must be at least 1-foot thick. The top of the clean sand layer must be level as must the rock layer which is placed upon the clean sand layer. Distribution pipes are placed in the clean rock. A sandy loam cap that is 6 inches thick at the side and 12 inches thick at the center is placed over the rock layer.

The purpose of the sandy cap is to avoid undue soil compaction so that the pore spaces are maintained, and soil air and moisture can move freely. The entire mound area is covered with a 6-inch layer of topsoil, upon which a grass cover should be established as soon as possible.

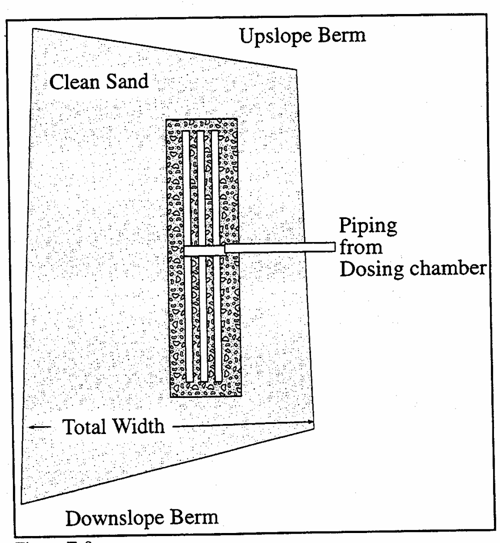


Figure E-8

Design Criteria Based on Analysis

The design material presented in this section suggests a possible approach. It is intended to deal primarily with mounds or "berms" for single-family residences, or daily sewage flow rates of no more than 1200 gallons. A flow of 1200 gallons per day can be treated with a rock bed 10 feet wide by 100 feet long in a properly constructed mound or berm. The proper hydraulic operation of a mound depends on lateral as well as vertical seepage.

Design Criteria: More Than Just Multiplying by a Scale Factor

The design criteria of this section cannot be simply multiplied by a scale factor and expected to properly treat larger flows. The hydraulics of lateral and vertical movement in the clean sand layer and the soil under the elevated rock bed must be carefully analyzed to ascertain that anaerobic conditions will not exist. Thus, both lateral and horizontal permeabilities of the underlying soil layers must be utilized to analyze the flow regime to estimate the height of the saturated zone.

Where heavy clay soils with slow permeabilities and high seasonal saturated conditions exist over an area, it is far better to utilize mounds for one or two single-family residences than to collect the effluent from many residences and attempt to dispose and treat it at a single location. The flow hydraulics in clay soils will require either large depths of fill, or underdrainage, or both, to design a proper sewage treatment system to prevent anaerobic conditions under the rock layer.

As an example, a mound designed to treat 450 gallons per day may function very well under certain clay soil conditions, while a single mound serving 5 or 10 residences may fail hydraulically if constructed according to the same vertical separation specifications.

Location and Ground Slope

Increased slope may mean faster percolation rate

Mounds should be located on slopes whenever possible. The present standards for locating mounds on slopes are found in Minnesota Rules, part 7080. These standards suggest that, as slope increases, the percolation rate of the topsoil increases allowing for the best site of the mounds.

Determining Specifications

Soil Sizing Factor

The soil sizing factor for the clean sand layer of the mound is 0.83 square feet per gallon of waste per day.

Area of Rock Layer

Rock Area = Flow x 0.83

To determine the area of rock layer required for a 4-bedroom, type I home,the estimated sewage flow rate of 600 gpd. Multiplying 600 gpd times 0.83 sq ft/gpd results in a rock layer area of 500 sq ft. The rock layer in a mound should be no wider than 10 feet, unless special design considerations are made. Thus, the shape of the rock layer required for a daily sewage flow of 600 gallons is 10 feet wide by 50 feet long.

Clean Sand Is Required

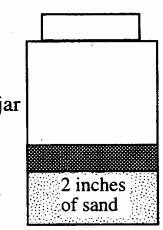
C-33 is Clean Sand

Sand is defined as a soil texture composed by weight of at least 25% of very coarse sand, and medium sand varying in size from 2.0 to 0.25 mm, less than 50% of fine or very fine sand ranging in size between 0.25 and 0.05 mm, and no more than 10% of particles smaller than 0.05 mm. Figure E-9 presents the jar test as a method for testing for clean sand.

25% Coarse
< 40% Fine Sand
< 10% Fines

Jar Test For
Clean Sand For Mounds

Use a
1 Quart
Mason jar



If the fines that
settle out in 1 hour
are greater than
1/8 inch
then the percentage
of fines is too great
and the sand **should not**
be used for mound
construction

Figure E-9

System Design

A vertical separation of at least 3 feet is required between the bottom of the rock bed and any restricting layer in order to maintain aerobic conditions and treat the waste water. (See Figure E-10)

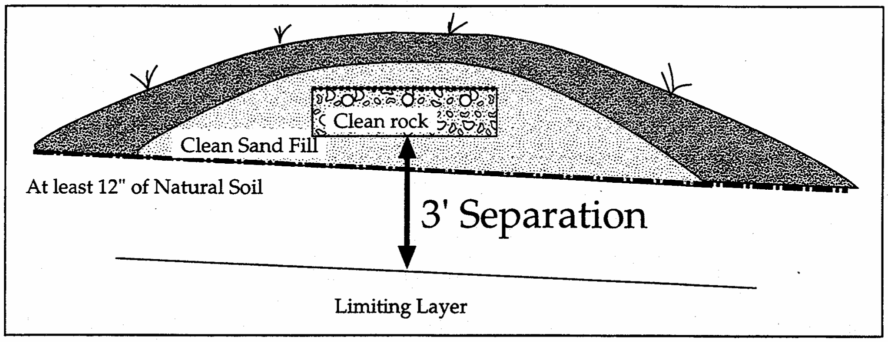


Figure E-10

When aerobic conditions exist in the clean sand, the long-term acceptance rate will be 1.2 gallons per day per square foot. If the depth to the restricting layer is inadequate or the rock bed is too wide, anaerobic conditions may exist and cause a much slower acceptance rate. The possibility of anaerobic conditions occurring in the clean sand and subsequent hydraulic failure is a major design consideration when mounds larger than those required for single-family residences are required.

A depth of at least 9 inches of drainfield rock should be placed on the sand layer prior to installing the distribution pipe. Drainfield rock is defined as clean rock, crushed igneous rock or similar insoluble, durable and decay-resistant material free from dust, sand, silt or clay. The size should range from 3/4 inch diameter to 2 1/2 inch diameter.

Rock Depth = 9 Inches

Size and Shape

❒ The bottom area of the drainfield rock shall be sized on the basis of 0.83 square feet per gallon of waste per day.

❒ In no case shall the width of the filter (rock) in a single bed exceed 10 feet.

Bed width < 10'

❒ A maximum of two 10-foot-wide rock beds may be installed side by side in a single mound if the soil percolation rate is between 5 and 60 mpi to a depth of at least 24 inches below the sand layer. The rock beds should be separated by at least 4 feet of sand.

Single rock beds are best

❒ Total area required by the mound depends on dimensions of the rock mound height and berm sideslopes.

What Is Absorption Width?

The absorption width of a mound is that width of soil under the sand layer that receives effluent. The width of the soil receiving effluent must have the capability to absorb this effluent; otherwise, berm toe surfacing will occur. (See Figure E-11)

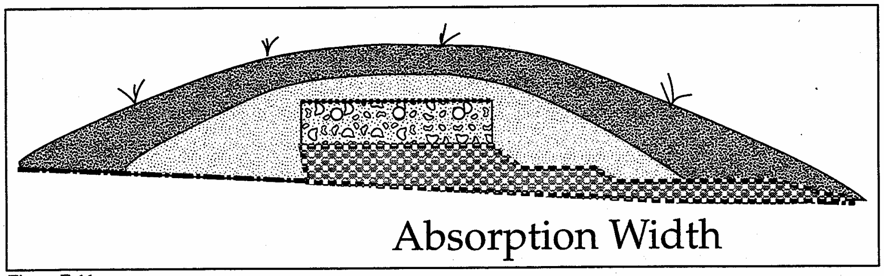


Figure E-11

Recent research and analysis have shown that the absorption width concept is the proper way to design a mound. If sufficient soil area is available for the downward percolating liquid to soak into the soil, then the relationship of slope and percolation rate is relatively unimportant. The percolation rate in the top foot of soil is used to determine the acceptance rate of the soil. As long as sufficient mound width is available so that all of the liquid is accepted into the soil and pressure distribution is used, berm toe surfacing should not occur. One of the major reasons for berm toe surfacing has been inadequate downslope berm widths. (See Figure E-12)

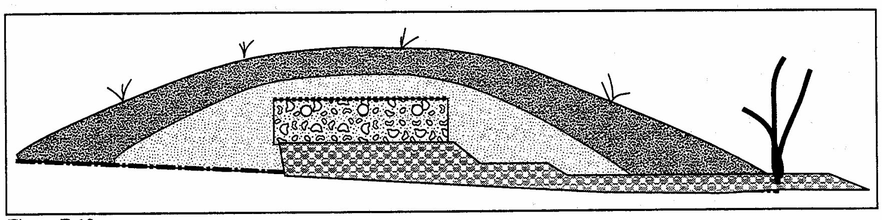


Figure E-12

On original soil with slopes of less than 1%, absorption width is equal to the sum of the upslope berm width, the rock layer width and the downslope berm width. Using the symbols in Figure E-15, absorption width equals $d_2 + W + d_1$. On ground sloping more than 1%, all of the effluent is assumed to move downslope and absorption width equals $d_2 + W$.

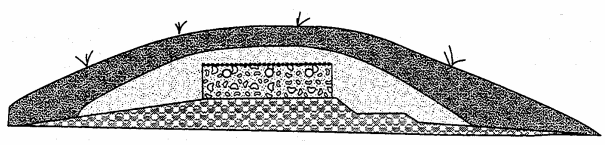


Figure E-13

Total absorption area is the product of the length of the rock layer and the absorption width. The berms located at the end of the rock layer are necessary for mound construction but the soil area under these berms is not considered part of the total absorption area.

How Much Absorption Width Is Required?

Adequate absorption width is essential to the successful operation of an onsite sewage treatment mound. The required absorption width depends upon the allowable loading rate of the soil under the clean sand layer of the mound. The allowable loading rate depends upon the percolation rate of the 1-foot layer of soil in contact with the clean sand layer of the mound. Allowable soil loading rates for various soil percolation rates are presented in Figure E-14.

Absorption Width Sizing Table

Percolation Rate in Minutes per Inch (MPI)	Soil Texture	Gallons per day per square foot	Ratio of Absorption width to Rock Layer Width
Faster than 0.1	Coarse Sand	1.20	1.00
0.1 to 5	Sand	1.20	1.00
0.1 to 5	Fine Sand	0.60	2.00
6 to 15	Sandy Loam	0.79	1.52
16 to 30	Loam	0.60	2.00
31 to 45	Silt Loam	0.50	2.40
46 to 60	Clay Loam	0.45	2.67
60 to 120	Clay	0.24	5.00
Slower than 120	Clay	0.20	6.00

Figure E-14

The downward percolation rate of original soil profiles in Minnesota have been measured on many slowly permeable soils. None of these original profiles has been found to have a vertical movement slower than 1 cm per day. This is a loading rate of 0.24 gpd/sq.ft.

Thus, if 1.20 gallons per day is the loading rate on a square foot of the clean sand, but the soil under the sand can absorb only 0.24 gallons per day per square foot, then 5.0 times as much absorption area must be available as sand areas in contact with the rock layer. Since only the side berms are used in the determination of absorption area, the term absorption width is preferred. Very little liquid will move out into the end berms of the mound.

Another way to express the absorption width requirement is to use the absorption width ratio, which is defined as the area of soil required to absorb the effluent percolating downward from one square foot of the rock layer.

Since the rock layer is sized on the basis of 0.83 square feet per gallon of wastewater per day, the loading rate is 1.2 gallons per day per square foot of area. If the soil under the clean sand layer does not have this absorption capability, then the effluent must be spread out over additional soil area.

For example, a soil having a percolation rate in the range of 61-120 mpi has an allowable loading rate of 0.24 gpd/ft^2 as shown in Figure E-14. Dividing the loading rate of the rock layer of 1.20 gpd/ft^2 results in a ratio of soil area to rock layer area of 5.00. This is the absorption width ratio for a soil having a percolation rate in the top foot of 61-120 mpi. As can be noted from Figure E-14, soils having faster percolation rates have greater allowable loading rates and consequently smaller absorption width ratios.

The width of a rock layer in a mound shall be no greater than 10 feet. A maximum of two 10-foot wide rock layers may be installed side by side in a single mound only if the soil percolation rate is between 5 and 60 mpi to a depth of at least 24 inches below the sand layer. The two rock layers shall be separated by 4 feet of clean sand. The reason for this requirement is to provide adequate absorption width and a sufficient depth of permeable soil to allow the liquid to move laterally.

A slide slope ratio of 4:0 (4 feet horizontal, 1 foot vertical) is the steepest berm slope allowed for mounds constructed on soils having a percolation rate of 61-120 mpi. The absorption width ratio may require even flatter side slopes in order to expose sufficient soil to effluent.

For mounds constructed on soils having percolation rates between 5 and 60 mpi, a berm slope ratio of 3 to 1 is the steepest allowed. A 4 to 1 berm slope ratio or flatter, however, is desirable for landscaping and maintenance.

Multipliers

Figure E-4 presents multipliers that are used to determine upslope and downslope berm widths. It will also allow calculation of downslope berm width for rock bed widths narrower than 10 feet.

Examples of Absorption Width Design

To achieve sufficient absorption width, it is occasionally necessary to use a narrower and longer rock layer. For the mound which was designed, a 10 x 50 foot rock layer was selected. On a slowly permeable soil, however, an 8-ft wide by 62.5-foot long rock layer would function better hydraulically.

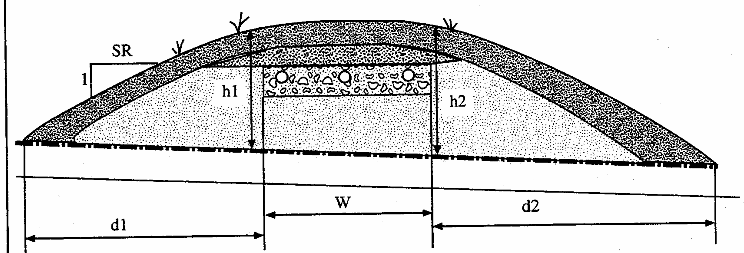
If this mound is located on an 8% slope, the downslope mound height, h_2, will be 3.0 + 0.08 x 8.0 or 3.64 feet. From Figure E-4, for a slope ratio of 4:1, the berm multiplier is 5.88. This value multiplied by the downslope berm height of 3.64 gives the value of 21.4 feet for d_2. The upslope berm multiplier is 3.03 for a slope ratio of 4:1. Since the upslope mound height is 3.0, the upslope berm width is 3.0 x 3.03 or 9.1 feet.

For example: The soil has a percolation rate of 50 mpi in the top foot and the site has a 6% slope. Mottled soil is located at the 2-foot depth. From Figure E-14, the absorption area loading rate is 0.45 gpd/ft^2 and the absorption width ratio is 2.67. If a 10-foot wide rock layer is used, the required absorption width is 26.7 feet (10 feet x 2.67).

Since the landslope is greater than 3%, only the width of the rock layer and the downslope berm are included in determining absorption widths. Thus, the width of the downslope berm included in determining absorption widths. Thus, the width of the downslope berm must be 16.7 feet (26.7-10.0).

To check the downslope berm dimensions for 3:1 and 4:1 berm slope rations, refer to Figure E-4. The downslope berm multiplier for a 3:1 slope is 3.65, which when multiplied by the mound height of 3.6 feet results in a downslope berm dimension of 13.2 feet. Since this is less than the required 16.7 feet, the berm slope ration must be flatter than 3:1.

The downslope berm multiplier for a 4:1 slope ratio is 5.26, which when multiplied by the mound height of 3.6 feet results in a downslope berm width of 18.9 feet. Since this dimension is greater than the required 16.7 feet, a berm slope ratio of 4:1 could be used.



SR = Slope ratio of horizontal distance per 1.0 foot vertical
S = Landslope in percent
h1 = Depth of mound on upslope edge of rock bed
h2 = Depth of mound on downslope edge of rock bed
W = Width of rock bed
d1 = Upslope dike width
d2 = Downslope dike width

Formulas:

$$d1 = \frac{h1\ SR}{1 + S/100\ SR} \qquad d2 = \frac{h2\ SR}{1 - S/100\ SR} \qquad h2 = h1 + W(S/100)$$

Figure E-15

Mound Width

The total width of the mound from berm to berm toe is shown on Figure E-15.

❒ Dimension d_1 is the upslope berm width, and dimension d_2 is the downslope berm width. The width of the rock layer is designated as W.

❒ The height of the mound above the original soil at the upper edge of the rock layer is designated as h_1 and the height at the downslope edge of the rock layer is designated as h_2.

❒ The slope of the berm is designated with a slope ratio (SR), which is the ratio of the horizontal distance to the vertical distance.

Mound Width Examples

For example: An SR of 3 indicated 3 feet horizontal to 1 foot vertical and would be equivalent to a slope of 33%. An SR of 4 is a flatter slope and is equivalent to a 25% slope. A table of those values is also presented for convenience.

On level ground, d_1 equals d_2. On sloping ground, d_2 becomes longer than d_1 when the slope ratio is the same for both berms.

The dimension h_1 is usually 3.0 feet, consisting of 1.0 foot of clean sand, 1.0 foot of rock layer, and 1.0 foot of soil cover over the rock. On level ground h_2 equals h_1, but on sloping ground h_2 is greater than h_1 because the top of the sand layer and the bottom of the rock layer must be level.

Mound Length

The length of the mound varies depending upon where it is measured. As can be seen from Figure E-8 in the plan view, the mound shape is trapezoidal. If the length is measured along the center of the rock layer, then the height of the mound at the end of the rock is 3.3 feet. If the berm slope ratio is 4:1, the berm will extend out 4.0 x 3.3 or 13.2 feet. The total length of the mound measured at the centerline of the rock layer will be 13.2 feet. The total length of the mound measured at the centerline of the rock layer will be 13.2 + 50 + 13.2 or 76.4 feet. The mound will be slightly longer near the base of the downslope berm and slightly shorter near the base of the upslope berm.

Several mound shapes are shown in Figures E-16 and E-17. The rectangular mound is most commonly used, since it is the easiest to construct. While the mound location depends upon soil suitability, every effort should be made to fit the mound into the landscape plan. Mounds can be used as privacy berms or to highlight a certain portion of the outdoor living area. While the mound must be functional for sewage treatment, the location and shape should also be functional in the landscape plan.

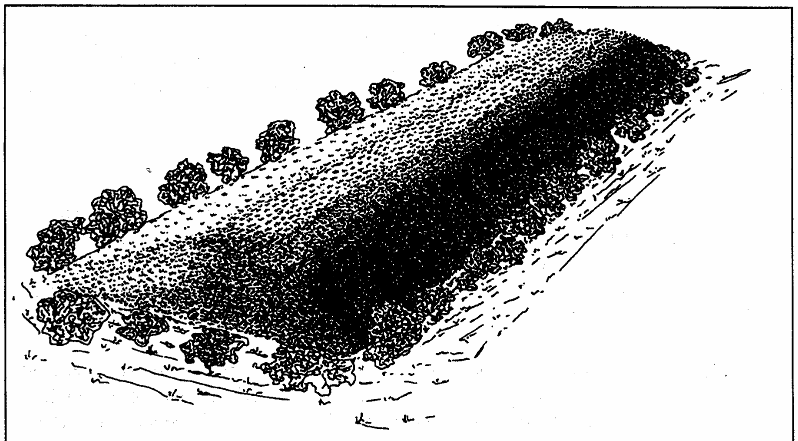


Figure E-16

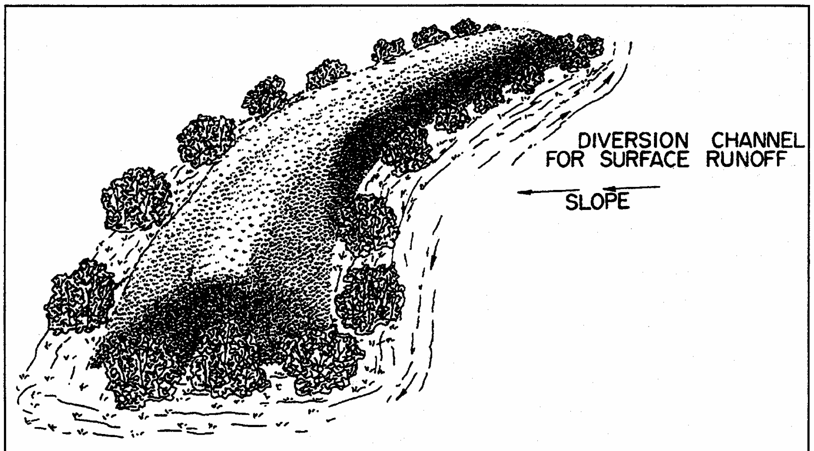


Figure E-17

Pump and Collection Tank

Install Alarm Device

A pump should be used to deliver effluent to the mound. A siphon will not be allowed as a closing device to deliver effluent to a pressure distribution system. An alarm device should be installed to warn of pump failure.

Adequate Treatment = Series of Small Doses

The quantity of effluent delivered to the mound each pump cycle should be no more than 25% of one day's sewage flow. The reason for this limit is to provide adequate treatment by having a series of small doses. The more doses, the better.

Pressure Distribution

Pressure distribution must be used for all mound systems. Effluent should be distributed over the rockbed by 1-inch to 1 1/2-inch diameter perforated pipe under pressure. Perforation holes shall be 3/16 to 1/4 inch in diameter drilled in a straight line along the length of the pipe.

< 10% loss in the System

The number of perforations and perforation spacings must not exceed 10% of the average pressure head on the perforations. Holes should be used and any burrs in the inside of the pipe should be removed. The perforated pipe laterals should be installed level with the perforations downward.

Distribution pipes used for pressure distribution must be constructed of sound and durable material not subject to corrosion, decay, or loss of strength under continuously wet conditions. All pipes and associated fittings used for pressure distribution must be properly joined together. The pipe and connections must be able to withstand a pressure of at least 40 pounds per square inch.

Pressure Fittings are Important

The perforated pipe laterals should be connected to a 2-inch diameter manifold pipe and should have ends capped. The laterals should be spaced no further than 40 inches on center and no further than 20 inches from the edge of the rock.

2" diameter manifold for all mounds

The manifold pipe should be connected to the supply pipe from the pump and should be sloped toward the supply pipe from the pump. At least 2 inches of rock should be placed over the distribution pipes.

Perforated Laterals

Figure E-18 shows a layout of perforated laterals to provide pressure distribution of effluent over the rock layer of a mound. The length of the perforated lateral is measured from the point where the effluent enters to the end cap. All connections in the pressure distribution system must be tight in order to prevent leakage and to withstand pressure.

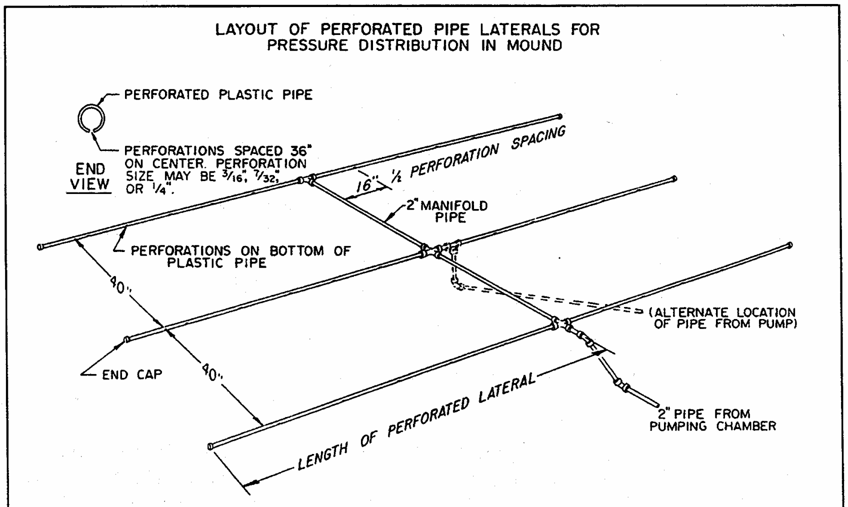


Figure E-18

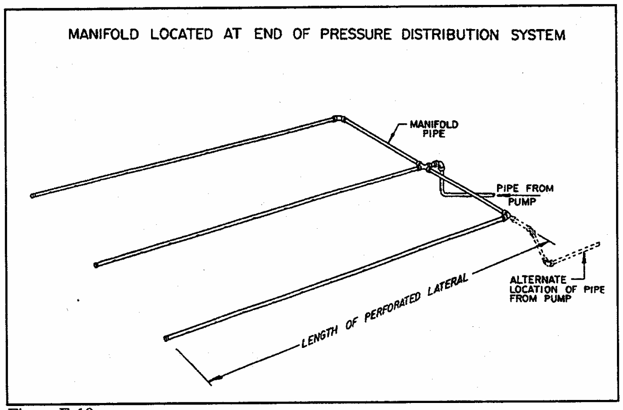


Figure E-19

The pipe from the pump can enter at the center of the manifold system (Figure E-18) or at the end (Figure E-19). The laterals can be connected to the manifold as shown in Figure E-18 or with a tee-to-tee lateral construction as shown in Figures E-20 and E-21.

Also as shown on Figure E-20, there should be a perforation drilled horizontally into the end cap of the perforated lateral near the top or crown.

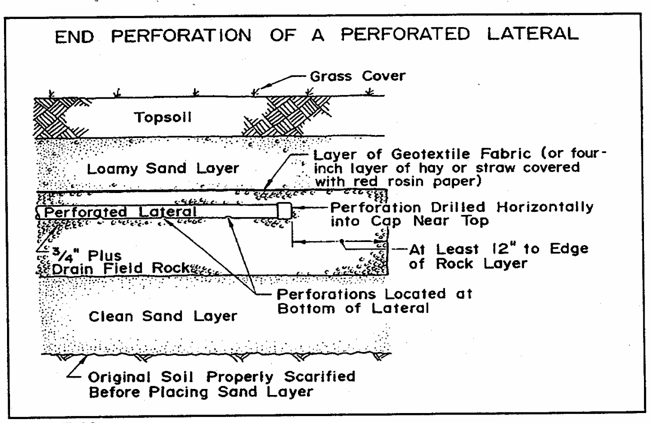


Figure E-20

For example: With 1/4-inch perforations spaced 36 inches apart, the maximum length that a 1-inch perforated lateral could extend would be 27 feet, the maximum length of a 1-1/4 inch lateral would be 42 feet, and the maximum length of a 1-1/2 inch lateral would be 54 feet. (See

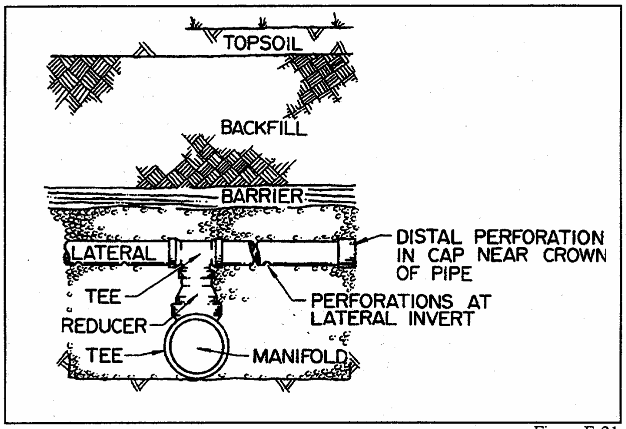


Figure E-21

Figure E-15) Using 1 inch or 1-1/4 inch diameter pipe would require that the manifold be located in the center of the rock layer. With the 1-1/2 inch size for the perforated laterals, the manifold could be located on one end as shown in Figure E-19.

As the lateral diameter increases, the maximum allowable length increases. Also, as the perforation size gets smaller, the maximum allowable length increases. The required pumping capacity is greater for a perforation spacing of 30 inches than 36 inches because there are more perforations. Also the required pumping capacity increases as the perforation diameter increases.

Another technique for determining the pumping capacity required for the perforated lateral system is to determine the number of perforations and multiply by the discharge per perforation. Assuming a 36-inch perforation spacing and a rock layer that is 50 feet long, a total of 17 perforations will be required for each perforated lateral.

The last perforation should be placed in the end cap of each lateral and should be at least one foot from the edge of the rock layer. There will be 3 laterals and a total of 51 perforations.

For a residential system, the head on the perforation should be at least 1.0 foot. The table of perforation discharges in Figure E-22 shows that 0.74 gpm will be discharged by a 1/4 inch perforation at a head of 1.0 foot. Multiplying 51 perforations by 0.74 gpm/perforation results in a total required flow rate of 37.7 gpm.

Perforation Discharges in GPM

Head	Perforation diameter (inches) 7/32	1/4
1.0a	0.56	0.74
1.5	0.69	0.90
2.0b	0.80	1.04
2.5	0.89	1.17
3.0	0.98	1.28
4.0	1.13	1.47
5.0	1.26	1.65

a Use 1.0 foot of head for residential systems.
b Use 2.0 feet of head for other esablishments.

Figure E-22

Friction Factors

Figure F-23 contains friction factors that can be used to calculate the friction loss in a perforated lateral. To use these "F" factors, the friction loss is first calculated as if the entire flow were moving through the entire length of the pipe.

In the previous example, each lateral would have a flow of 37.7/3 = 12.6 gpm. The friction loss for 12.6 gpm should be calculated for 48 lineal feet of the pipe diameter under consideration. This total friction loss is then multiplied by an "F" factor which is 0.374 for a pipe having 17 outlets.

Friction Loss Should Be No More Than 2% of Average Operating Pressure

The friction loss in the pipe with multiple outlets should not be greater than 2% of the average operating pressure; in this case, 1.0 foot. Thus the maximum allowable friction loss would be 0.20 foot, and the difference in discharge between the first and last perforation along the perforated lateral will be less than 10%.

"F" Factors for a Pipe with Multiple Outlets

Number of Perforations	"F" Factor
6	0.432
8	0.409
10	0.396
12	0.387
14	0.380
16	0.376
18	0.372
20	0.370
30	0.360

Figure E-23

By using the "F" factor in Figure E-23 and the friction loss for plastic pipe presented in Figure F-14, the maximum allowable number of various size perforations that are allowed on various diameter laterals were calculated and are presented in Figure E-24. This table is suitable only for the perforations listed. Similar tables may be developed for other perforation diameters.

Maximum allowable number of quarter inch perforations per lateral to guarantee <10% Discharge variation

perforation spacing (feet)	1.25 inch	1.5 inch	2.0 inch
2.5	14	18	28
3.0	13	17	26
3.3	12	16	25
4.0	11	15	23
5.0	10	14	22

Figure E-24

Three Layers in Mound Construction

The contractor is primarily responsible for proper mound construction. There are three layers that, if not treated properly, can create problems with the hydraulic performance of the mound.

Natural Soil

First Layer = Natural Soil

The first layer is the natural soil on which the mound is to be constructed. If this soil is wetter than the plastic limit, or if considerable construction activity has caused compaction, then the ability of the soil to transmit liquid will have been seriously reduced.

For proper hydraulic performance, there should be at least 3 feet of natural or clean sand above the limiting soil condition. This could be 3 feet of natural soil above a saturated layer, it could be 2 feet of natural soil plus 1 foot of clean sand, or it could be 2 feet of clean sand. Unless the soil under the mound has the ability to transmit liquid both vertically and horizontally, the mound will not function properly.

Soil Surface

Second Layer = Soil Surface

Another critical layer that is essential to proper mound performance is the soil surface on which the clean sand layer is placed. Soil surface preparation should be carefully studied. Once the clean sand layer is in place, it will be extremely difficult for the inspector to determine how the soil surface was prepared prior to sand placement.

A soil surface that has been smeared, compacted or otherwise made unsuitable for the movement of liquid through it will not recover that capacity after a period of time. Liquid will likely seep out of the mound at the toe of the berm or at the edge of the rock layer.

Soil Surface Preparation

The discharge pipe from the pump to the mound area should be installed prior to soil surface preparation. The trench excavated to install the discharge pipe should be carefully backfilled and compacted to prevent seepage of effluent.

All vegetation in excess of 4 inches in length and dead organic debris must be removed from the surface of the total area under the mound. (See Figure E-25)

The total area selected for the mound, including that under the berms, should be roughened to thoroughly break up any existing sod layers and to provide a suitable transition zone between the original soil and the plastic limit.

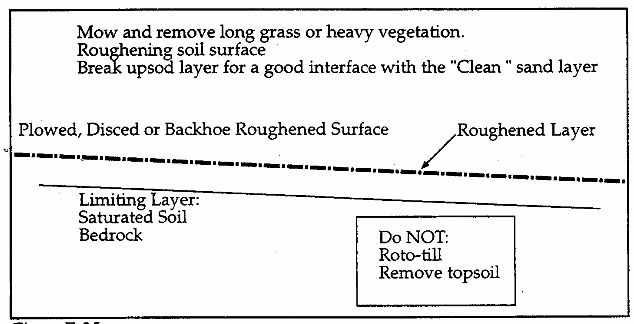


Figure E-25

Plastic Limit

Plastic limit is the soil moisture content below which the soil may be manipulated for purposes of installing a soil treatment system, and above which manipulation will cause compaction and puddling.

Plastic Limit = 1/8 inch Soil Wire

If a fragment of soil can easily be rolled into a wire 1/8 inch in diameter, the moisture content is above plastic limit.

If the soil is dry enough to be friable and falls apart when rolling it into wire, the moisture content is below the limit and soil may be manipulated.

The standard method of determining the plastic limit is specified in the American Association of State Highway Officials (AASHO) Designation: T 90-61.

Roughening

Surface preparation or roughening may be performed with a mold board plow, a disk plow or a backbone using only the teeth. Mold board plow furrows shall be at least 8 inches deep, should be thrown upslope and should run perpendicular to the slope. There should be no dead furrow under the mound. Never use a rototiller to prepare the surface.

No Rototilling

Disking may be used to roughen the soil surface and break up the sod layer. Care must be taken so as not to compact or puddle deeper soil layers. In no case should any surface soil be excavated and moved more than one foot from its original location.

Mound construction should proceed immediately after surface preparation is completed. Every effort should be taken to prevent rain from falling on the prepared soil surface.

Protec t soil surface from rain

Construction Equipment

A rubber-tired tractor may be used for plowing or disking to prepare the soil surface, but in no case should a rubber-tired tractor be used after the surface preparation is completed. A crawler or track-type tractor should be used for mound construction, where the soil percolation rate is slower than 15 minutes per inch. A minimum 6-inch layer of sand must be kept below the equipment during construction.

Clean Sand Layer

The other layer over which the contractor has responsibility, but which can easily be checked by the inspector, is the texture of the clean sand layer. Clean sand, described on the basis of a sieve analysis, is a soil texture composed by weight of at least 25% of very coarse, coarse and medium sand varying in size from 2.0 to 0.25 mm, less than 50% of fine or very fine sand ranging in size between 0.25 and 0.05 mm, and no more than 10% of particles smaller than 0.05 mm.

Third Layer = Clean Sand

Clean sand can also easily be determined by using the fruit jar test. This is the same test that was mentioned in Figure E-9. Place exactly 2 inches of sand in the bottom of a quart fruit jar and then fill the jar three-fourths full of water. Place the cover on the jar and shake the contents vigorously.

Allow the jar to stand for about an hour and observe whether there is a layer of silt or clay on top of the sand. If the layer of these fine particles is more than 1/8 inch thick, the sand is likely not suitable for use in mound construction, because too many fine particles tend to cause the soil to compact during the construction process. Also, the long-term acceptance rate of this soil will be slower than the long-term acceptance rate of clean sand, which is used for sizing the rock layers.

Construction Materials and Procedures

A minimum of 12" of soil defined as sand should be placed where the drainfield rock is to be located. A crawler tractor with a blade or bucket shall be used to move the sand in to place. At least 6 inches of sand should be kept under the tracks to minimize compaction of the plowed layer. When placing sand with a backhoe that has rubber tires, the tractor must not drive over the drainfield rock or mound berms. The sand layer upon which the drainfield rock is placed should be level. (See Figure E-26)

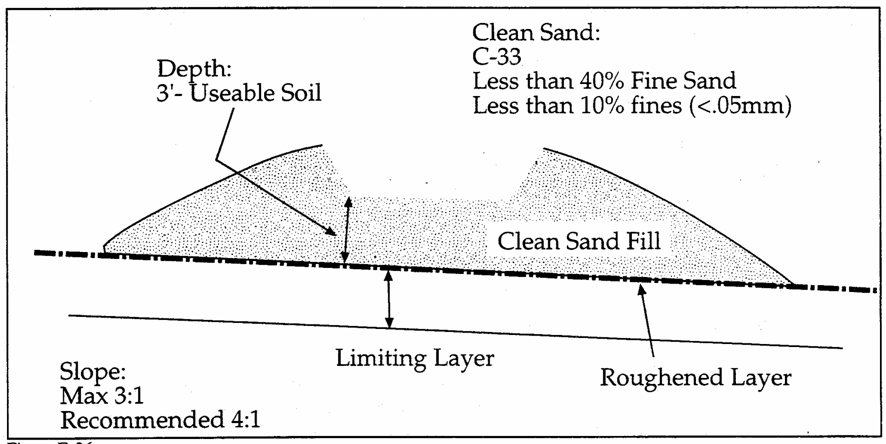


Figure E-26

Cover Material

Geotextile must be used over the rock bed. This fabric should allow air and water to move through, but catch all fine materials. Construction vehicles should not be allowed on the rock until backfill is placed.

Sandy soil should be placed on the rock to a depth of 12 inches in the center of the mound and to a depth of 6 inches at the sides.

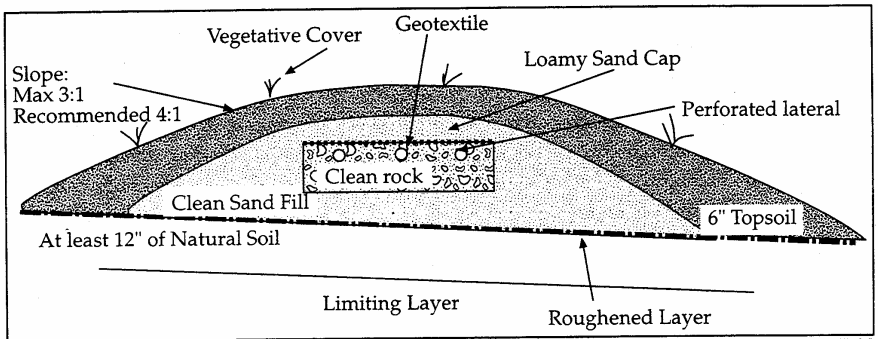


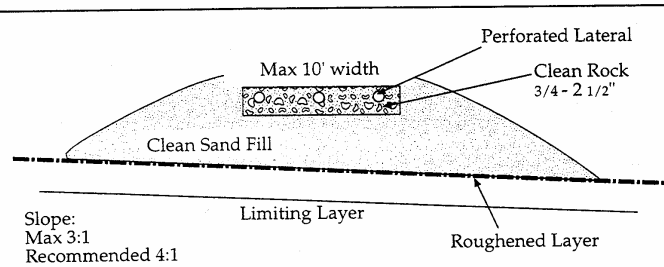
Figure E-27

When the two beds are installed side by side, the sandy loam fill at the center of the mound should be 18 inches deep and 6 inches deep at the sides.

Six inches of topsoil should be placed on the rock over the entire area of the mound. A grass cover should be established over the entire area of the mound. No shrubs should be planted on the top of the mound. Shrubs may be placed at the foot and side slopes of the mound. Be sure that the planted shrubs can handle the wet environment.

Side slopes of 4 feet horizontal to 1 foot vertical (4:1) are suggested for the berms of the mound. This gentle slope will allow easy mowing of the grass cover. If area is limited, steeper side slopes of 3:1 can be used. In no case, however, should the berm slope be steeper than 3:1.

Whenever mounds are located on slopes a diversion shall be constructed immediately upslope from the mound to intercept and divert runoff.



12" layer of clean rock and pressure pipe in place.
Bottom and top of rock layer must be level.
Rock must be clean and free of fine material and debris.
Size of the rock is 3/4 inch tp 2 1/2 inch.
9" of rock must be placed under the pressure pipe and 2" above.

Figure E-28

Mound Dimensions

Slope	Upslope Berm (feet)	Rockbed	Downslope Berm <60 MPI	60 MPI - 120MPI
0%	16	10'	17	30
1%	15.4	10'	17	40
2%	14.8	10'	18.3	40
3%	14.3	10'	19.4	40
4%	13.8	10'	21	40
5%	13.3	10'	22.5	40
6%	12.9	10'	24.4	40
7%	12.5	10'	26	40
8%	12.1	10'	28.3	40
9%	11.8	10'	30.6	40
10%	11.4	10'	33.4	40
11%	11.2	10'	36.4	40
12%	10.8	10'	40	40

The system length is the flow ÷ the bed width plus the upslope berm twice.

Length = (______÷10) + _______ + _______

Figure E-29

The setback for mound systems is based on the absorption area on the downslope side. This chart is a quick reference for these dimensions.

Percolation Rate in Minutes per Inch (MPI)	Soil Texture	Downslope setback to Rock Layer
Faster than 0.1	Coarse Sand	5
0.1 to 5	Sand	5
0.1 to 5	Fine Sand	10
6 to 15	Sandy Loam	5
16 to 30	Loam	10
31 to 45	Silt Loam	14
46 to 60	Clay Loam	17
60 to 120	Clay	40
Slower than 120	Clay	50

Figure E-31

Location of Soil Treatment System

Item	Setback Distance
Water supply well less than 50 feet of casing and not encountering 10 feet of impervious material	100
Any water supply well or buried water suction pipe	50
Building	20
Streams, Lakes or other bodies of water (Shoreland Management Act)	50,75,150
Property lines or buried pipe distributing water under pressure	10

Figure E-30

PART III: SYSTEMS FOR SOILS WITH RAPID PERMEABILITY

Systems for Rapidly Permeable Soils

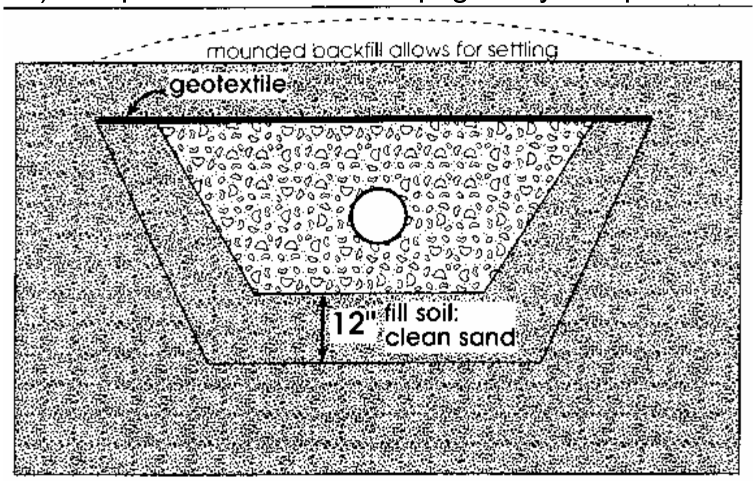
Soils in this category have low treatment capabilities and require special design considerations to design systems that will overcome this limitation.

Perc Rates Faster than 1 mpi: Coarse Sands and Gravels

Soil treatment systems in soils with percolation rates faster than 1 mpi, or in coarse sand and gravel, must use one of the following:

- a mound system, or
- a liner system.

A liner system consists of trenches with at least 12 inches of clean sand placed between the drainfield rock and the coarse soil along the excavation bottom and sidewall. The treatment area is sized at 0.60 or 1.67 sqft/gal/day (see Figure D-54) or if pressure dose is 1 sqft/gal/day see pressure distribution section.



Perc Rates Less than 1 mpi: Sands and Gravels

The concern with these soils is poor distribution and little or no treatment by overloading of the trench before the biomat is formed. Soils that contain a large percentage of rocks or coarse particles (greater than two millimeters) provide poor treatment, due to the “dilution” of the soil.

PART IV: DRIP IRRIGATION

This has been reprinted from the USEPA Onsite Wastewater Treatment Systems Manual.

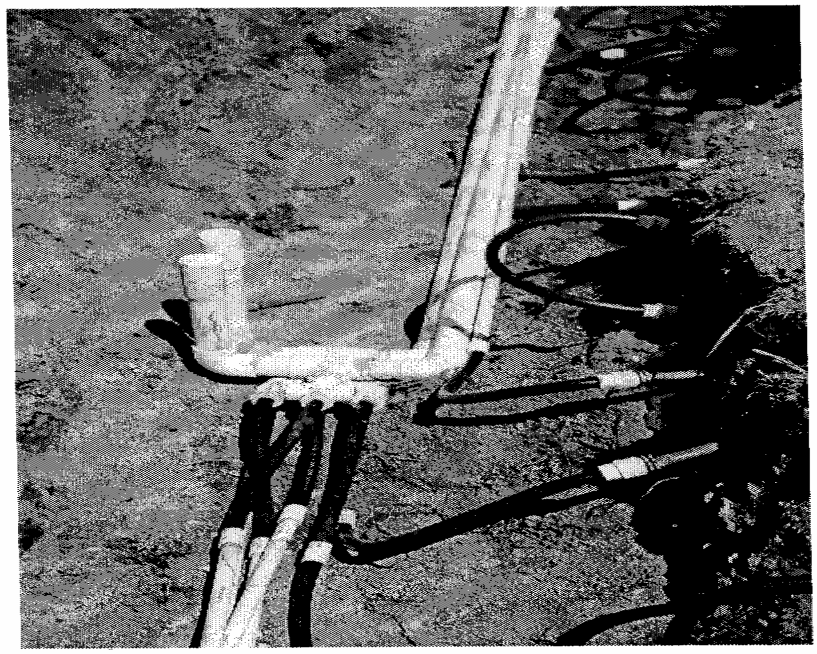
Dripline pressure network

Drip distribution, which was derived from drip irrigation technology, was recently introduced as a method of wastewater distribution. It is a method of pressure distribution capable of delivering small, precise volumes of wastewater effluent to the infiltration surface. It is the most efficient of the distribution methods and is well suited for all types of lateral applications. A dripline pressure network Consists of several components:

- Dose tank
- Pump
- Prefilter
- Supply manifold
- Pressure regulator (when turbulent, flow emitters are used)
- Dripline
- Emitters
- Vacuum release valve
- Return manifold
- Flush valve
- Controller

The pump draws wastewater effluent from the dose tank, preferably on a timed cycle, to dose the distribution system. Before entering the network, the effluent must be prefiltered through mechanical or granular medium filters. The former are used primarily for large lateral systems. The backflush water generated from a self-cleaning filter should be returned to the headworks of the treatment system. The effluent enters the supply manifold that feeds each dripline (figure 4-17). If turbulent flow emitters are used, the filtered wastewater must first pass through a pressure regulator to control the maximum pressure in the dripline. Usually, the dripline is installed in shallow, narrow trenches 1 to 2 feet apart and only as wide as necessary to insert the dripline using a trenching machine or vibratory plow. The trench is backfilled without any porous medium so that the emitter orifices are in direct contact with the soil. The distal ends of each dripline are connected to a return manifold. The return manifold is used to regularly flush the dripline. To flush, a valve on the manifold is opened and the effluent is flushed through the driplines and returned to the treatment system headworks.

Figure 4-17. Pressure manifold and flexible drip lines prior to trench filling



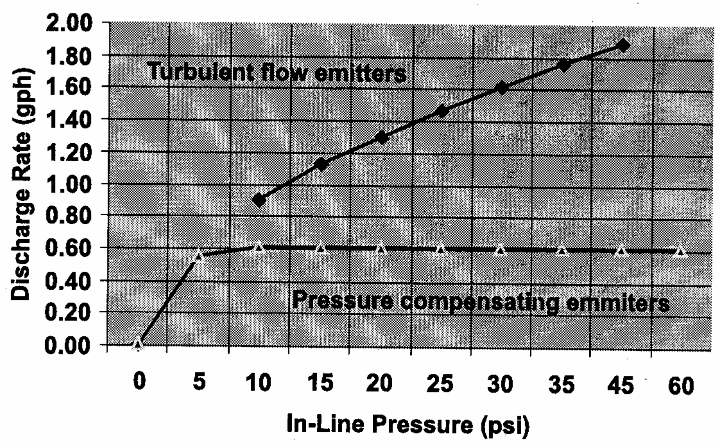
Source: Ayres Associates.

Because of the unique construction of drip distribution systems, they cause less site disruption during installation, are adaptable to irregularly shaped lots or other difficult site constraints, and use more of the soil mantle for treatment because of the shallow depth of placement. Also, because the installed cost per linear foot of dripline is usually less than the cost of conventional trench construction, dripline can be added to decrease mass loadings to the infiltration surface at lower costs than other distribution methods. Because of the equipment required, however, drip distribution tends to be more costly to construct and requires regular operation and maintenance by knowledgeable individuals. Therefore, it should be considered for use only where operation and maintenance support is ensured.

The dripline is normally a ½-inch-diameter flexible polyethylene tube with emitters attached to the inside wall spaced 1 to 2 feet apart along its length. Because the emitter passageways are small, friction losses are large and the rate of discharge is low (typically from 0.5 to nearly 2 gallons per hour).

Two types of emitters are used. One is a "turbulentflow" emitter, which has a very long labyrinth. Flow through the labyrinth reduces the discharge pressure nearly to atmospheric rates. With increasing in-line pressure, more wastewater can be forced through the labyrinth. Thus, the discharges from turbulent flow emitters are greater at higher pressures (figure 4-18). To more accurately control the rate of discharge, a pressure regulator is installed in the supply manifold upstream of the dripline. Inlet pressures from a minimum of 10 psi to a maximum of 45 psi are recommended. The second emitter type is the pressure-compensating emitter. This emitter discharges at nearly a constant rate over a wide range of in-line pressures (figure 4-18).

Figure 4-18. Turbulent-flow and pressure-compensating emitter discharge rates versus in-line pressure



Head losses through driplines are high because of the small diameter of the tubing and its in-line emitters, and therefore dripline lengths must be limited. Manufacturers limit lengths at various emitter spacing. With turbulent flow emitters, the discharge from each successive emitter diminishes in response to pressure loss created by friction or by elevation changes along the length of the dripline. With pressure-compensating emitters, the in-line pressure should not drop below 7 to 10 psi at the final emitter. The designer is urged to work with manufacturers to ensure that the system meets their requirements.

Pressure-compensating emitters are somewhat more expensive but offer some important advantages over turbulent-flow emitters for use in onsite wastewater systems. Pressure-compensating dripline is better suited for sloping sites or sites with rolling topography where the dripline cannot be laid on contour. Turbulent-flow emitters discharge more liquid at lower elevations than the same emitters at higher elevations. The designer should limit the difference in discharge rates between emitters to no more than 10 percent. Also, because the discharge rates are equal when under pressure, monitoring flow rates during dosing of a pressure-compensating dripline network can provide an effective way to determine whether leaks or obstructions are present in the network or emitters. Early detection is important so that simple and effective corrective actions can be taken. Usually, injection of a mild bleach solution into the dripline is effective in restoring emitter performance if clogging is due to biofilms. If this action proves to be unsuccessful, other corrective actions are more difficult and costly. An additional advantage of pressure-compensating emitters is that pressure regulators are not required. Finally, when operating in their normal pressure range, pressurecompensating emitters are not affected by soil water pressure in structured soils, which can cause turbulent-flow emitters to suffer reduced dosing volumes.

Controlling clogging in drip systems

With small orifices, emitters are susceptible to clogging. Particulate materials in the wastewater, soil particulates drawn into an emitter when the dripline drains following a dose, and biological slimes that grow within the dripline pose potential clogging problems. Also, the moisture and nutrients discharged from the emitters may invite root intrusion through the emitter. Solutions to these problems lie in both the design of the dripline and the design of the distribution network. Emitter hydrodynamic design and biocide impregnation of the dripline and emitters help to minimize some of these problems. Careful network design is also necessary to provide adequate safeguards. Monitoring allows the operator to identify other problems such as destruction from burrowing animals.

To control emitter clogging, appropriate engineering controls must be provided. These include prefiltration of the wastewater, regular dripline flushing, and vacuum release valves on the network. Prefiltration of the effluent through granular or mechanical filters is necessary. These filters should be capable of removing all particulates that could plug the emitter orifices. Dripline manufacturers recommend that self-cleaning filters be designed to remove particles larger than 100 to 115 microns. Despite this disparate experience, pretreatment with filters is recommended in light of the potential cost of replacing plugged emitters. Regular cleaning of the filters is necessary to maintain satisfactory performance. The backflush water should be returned to the head of the treatment works.

The dripline must be flushed on a regular schedule to keep it scoured of solids. Flushing is accomplished by opening the flush valve on the return manifold and increasing the pumping rate to achieve scouring velocity. Each supplier recommends a velocity and procedure for this process. The flushing rate and volume must include water losses (discharge) through the emitters during the flushing event. Both continuous flushing and timed flushing are used. However, flushing can add a significant hydraulic load to the treatment system and must be considered in the design. If intermittent flushing is practiced, flushing should be performed at least monthly.

Aspiration of soil particles is another potential emitter clogging hazard. Draining of the network following a dosing cycle can create a vacuum in the network. The vacuum can cause soil particles to be aspirated into the emitter orifices. To prevent this from occurring, vacuum relief valves are used. It is best to install these at the high points of both the supply and return manifolds.

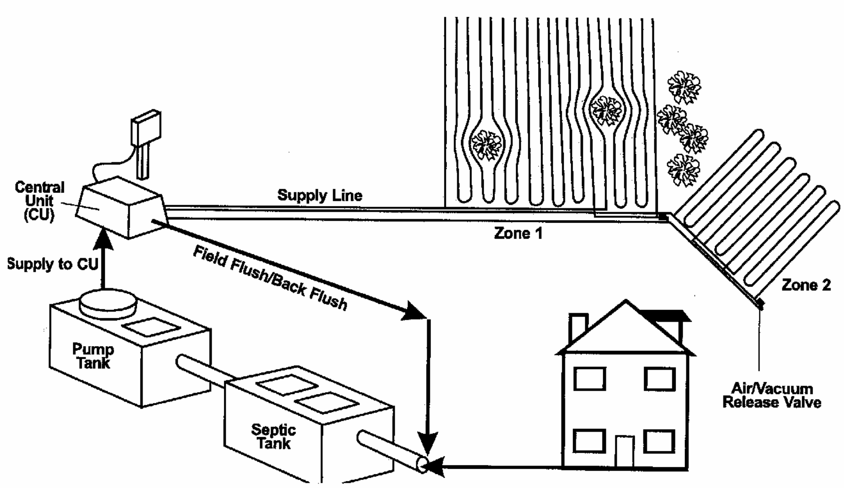
Placement and layout of drip systems

When drip distribution was introduced, the approach to sizing drips using this distribution method was substantially different from that for laterals using other distribution methods. Manufacturer-recommended hydraulic loading rates were expressed in terms of gallons per day per square foot of drip distribution footprint area. Typically, the recommended rates were based on 2-foot emitter and dripline spacing. Therefore, each emitter would serve 4 square feet of footprint area. Because the dripline is commonly plowed into the soil without surrounding it with porous medium, the soil around the dripline becomes the actual infiltration surface. The amount of infiltration surface provided is approximately 2/3 to 1 square foot per 5 linear feet of dripline. As a result, the wastewater loading rate is considerably greater than the hydraulic loadings recommended for traditional laterals. Experience has shown however, that the hydraulic loading on this surface can be as much as seven times higher than that of traditional lateral designs (Ayres Associates, 1994). This is probably due to the very narrow geometry, higher levels of pretreatment, shallow placement, and intermittent loadings of the trenches, all of which help to enhance reaeration of the infiltration surface.

The designer must be aware of the differences between the recommended hydraulic loadings for drip distribution and those customarily used for traditional laterals. The recommended drip distribution loadings are a function of the soil, dripline spacing, and applied effluent quality. It is necessary to express the hydraulic loading in terms of the footprint area because the individual dripline trenches are not isolated infiltration surfaces. If the emitter and/or dripline spacing is reduced, the wetting fronts emanating from each emitter could overlap and significantly reduce hydraulic performance. Therefore, reducing the emitter and/or dripline spacing should not reduce the overall required system footprint. Reducing the spacing might be beneficial for irrigating small areas of turf grass, but the maximum daily emitter discharge must be reduced proportionately by adding more dripline to maintain the same footprint size. Using higher hydraulic loading rates must be carefully considered in light of secondary boundary loadings, which could result in excessive ground water mounding (see chapter 5). Further, the instantaneous hydraulic loading during a dose must be controlled because storage is not provided in the dripline trench. If the dose volume is too high, the wastewater can erupt at the ground surface.

Layout of the drip distribution network must be considered carefully. Two important consequences of the network layout are the impacts on dose pump sizing necessary to achieve adequate flushing flows and the extent of localized overloading due to internal dripline drainage. Flushing flow rates are a function of the number of manifold/dripline connections: More connections create a need for greater flushing flows, which require a larger pump. To minimize the flushing flow rate, the length of each dripline should be made as long as possible in accordance with the manufacturer's recommendations. To fit the landscape, the dripline can be looped between the supply and return manifolds (figure 4-19). Consideration should also be given to dividing the network into more than one cell to reduce the number of connections in an
individual network. A computer program has been developed to evaluate and optimize the hydraulic design for adequate flushing flows of dripline networks that use pressure-compensating emitters (Berkowitz and Harman, 1994).

Figure 4-19. Dripline layout on a site with trees



Source: Adapted from American Manufacturing, 2001.

Internal drainage that occurs following each dose or when the soils around the dripline are saturated can cause significant hydraulic overloading to lower portions of the system. Following a dose cycle, the dripline drains through the emitters. On sloping sites, the upper driplines drain to the lower driplines, where hydraulic overloading can occur. Any free water around the dripline can enterthrough an emitter and drain to the lowest elevation. Each of these events needs to be avoided as much as possible through design. The designer can minimize internal drainage problems by isolating the driplines from each other in a cell, by aligning the supply and return manifolds with the site's contours. A further safeguard is to limit the number of doses per day while keeping the instantaneous hydraulic loadings to a minimum so the dripline trench is not flooded following a dose. This tradeoff is best addressed by determining the maximum hydraulic loading and adjusting the number of doses to fit this dosing volume.

Freezing of dripline networks has occurred in severe winter climates. Limited experience indicates that shallow burial depths together with a lack of uncompacted snow cover or other insulating materials might lead to freezing. In severe winter climates, the burial depth of dripline should be increased appropriately and a good turf grass established over the network. Mulching the area the winter after construction or every winter should be considered. Also, it is good practice to install the vacuum release valves below grade and insulate the air space around them. Although experience with drip distribution in cold climates is limited, these safeguards should provide adequate protection.

PART V: FREEZING

The following paper was copied from University of Minnesota and some of the references are to contact Minnesota. We recommend contacting the county sanitarian or the IDNR if you have questions.

UNIVERSITY OF MINNESOTA
ONSITE SEWAGE TREATMENT PROGRAM

Freezing Problems with Onsite Sewage Treatment Systems

Sara Christopherson and Ken Olson

Why Might an Onsite System Freeze?

According to many onsite professionals this has been a very hard year for onsite septic systems due to the lack of snow cover combined with cold temperatures. Even in a normal Minnesota winter, freezing can occasionally be a problem. Identifying and correcting a potential freezing problem is far easier than dealing with a frozen system. Here are a few common causes of onsite system freeze-ups.

Lack of Snow Cover: Snow serves as an insulating blanket over the septic tank(s) and soil treatment area (trenches, drainfield or mound). Snow helps keep the heat of the sewage and the heat created by the treatment of the sewage in the soil. Lack of snow allows frost to go deeper into the ground, potentially freezing the system.

Compacted Snow: Compacted snow will not insulate as well as uncompacted snow. Driving any type of equipment over the system compacts snow and sends the frost down deeper. Automobiles, snowmobiles, ATV's, people, and large livestock should stay off the system all year long but especially in the winter. Anytime traffic over a sewer pipe, septic tank, or soil treatment area is anticipated, insulated pipe should be used.

Compacted Soils: Areas that have compacted soils, such as driveways, paths or livestock enclosures, tend to freeze deeper, affecting septic system components that may be in the area.

Lack of Plant Cover: This often occurs in new systems installed late in the fall where a vegetative cover could not be established before winter. The vegetative cover insulates the system and helps hold snow.

Irregular Use of System: When homes or cabins are unoccupied for long weekends or extended periods of time, no sewage is entering the system to keep it warm. This can also occur when very low volumes of sewage are being generated. In cases when only one or two people are living in a home, they may use only a small percentage of the designed flow rate of 150 gallons per bedroom. Low usage may not be sufficient to keep the system from freezing. Frequent use, warm water temperatures and total volume of sewage are all important in cold temperature stress situations.

Leaking Plumbing Fixtures: When a fixture such as a toilet or shower leaks, it sends a very small trickle of sewage to the system. This trickle can freeze within the pipe and eventually cause the pipe to freeze solid. Appliances such as high efficiency furnaces and humidifiers can also cause water to freeze in the pipes due to the small amount of discharge.

Pipes Not Draining Properly: A common cause of freeze-ups are sewer pipes and pump lines that are not installed with proper fall (change of elevation) or pipes that settle after installation. Anytime a dip or low spot occurs in a pipe, sewage can collect and freeze. Pump lines can develop a dip right next to or above the septic tank as a result of backfilled soil settling from the excavation during the tank installation. It is important that all sewage drains out of the pipe from a pump line.

Cold Air Entering the System: Open and uncapped riser or inspection pipes and manhole covers allow cold air into the system and can cause the system to freeze.

Water Logged System: If a system was hydraulically failing (e.g. water coming to surface or seeping out the side of a mound) in the fall, it is a prime candidate to freeze. This effluent will freeze and prevent further effluent from entering the soil.

What Should You Do If Your Onsite System Freezes?

If your septic system is frozen, your first step is to call an onsite professional. If you have a pump and hear water constantly running in a pump tank (a possible indication of a frozen system) disconnect your pump and call an onsite professional. This will likely be a pumper or an installer who can help determine the cause of the problem and offer solutions. The U of M Onsite Program web site is one place to go to locate a professional - http://septic.coafes.umn.edu/homeowner/index.html. Many pumpers and installers have devices called steamers and high-pressure jetters to try to unfreeze system piping. Unless the cause of freezing is corrected the piping will refreeze. Other methods used to help fix a freezing problem include adding heat tape and tank heaters. Cameras can be sent down the pipes to determine where the freezing is occurring and if repairs are needed. If the treatment area is full of ice, or there is evidence of leaking, there is no need to thaw the lines leading to the treatment area, as it cannot accept liquid until the area is thawed in spring.

If it is not feasible to correct the problem or equipment is not available in your area, the only other option is to use the septic tank(s) in the system as a holding tank until the system thaws naturally. You will need to contact a pumper who will empty out the tanks when they are full on a regular basis. This can be very costly, especially with normal volumes of water use (50 to 75 gallons per person per day). Reduce water use by limiting the number of toilet flushes, taking short showers, using the dishwasher at full capacity, limiting running water to get hot or cold and doing laundry at a laundromat. It is smart to find the cause of the freezing problem so that it can be addressed in the spring, preventing future freeze-ups.

There are many misconceptions about how to deal with a frozen onsite system.

- Do NOT add antifreeze, salt or a septic system additive into the system.
- Do NOT pump sewage onto the ground surface.
- Do NOT start a fire over the system to attempt to thaw it out.
- Do NOT run water continually to try to unfreeze system.

What Can You Do to Prevent Your Onsite System From Freezing in the Future?

Depending on your system, location, and water use, you may never have a freezing problem. However, there are several steps that you can take if you are concerned about your onsite system freezing. Here are some precautions if you have had a past problem or are concerned about having a future problem. It is not necessary to do all of these, but you may pick and choose based on your situation:

1. Place a layer of mulch (8-12 inches) over the pipes, tank and soil treatment system to provide extra insulation. This mulch could be straw, leaves, hay or any other loose material that will not compact and stay in place. This is particularly important if you have had a new system installed late in the year and no vegetative cover has been established. If your system is currently frozen ignore this step, as it will delay thawing come spring.
2. Let the grass in your lawn get a little longer in the late summer/fall over the tank and soil treatment area. This will provide extra insulation and help hold any snow that may fall.
3. Use water; the warmer the better! The Onsite Sewage Treatment Program is usually an advocate of water conservation, but if freezing is a concern, increasing low use to a normal water use can help the system. This includes spreading out your laundry schedule to possibly doing one warm/hot load per day, using your dishwasher and maybe even taking a hot bath. DO NOT leave water running all the time, as this will hydraulically overload the system.
4. If you know you are going to be gone for an extended period, plan accordingly. This could include having someone use sufficient quantities of water in the home regularly or pumping out your tank before leaving. If you live in an area with a high water table, you should only pump out the tank if the tank was designed for high water table conditions. If a tank is left full for several winter months, the sewage will get very cold in shallow tanks and can even freeze. If you then return home before temperatures start to rise, the effluent leaving the tank will be cold. By starting with an empty tank, you can then start fresh with warm effluent. If you use a cabin on a limited basis during the winter months, this may be a good idea as well.
5. Fix any leaky plumbing fixtures or appliances in your home. This will help prevent freezing problems and help your system work better year round. If you have appliances that generate very low flows such as high efficiency furnaces, you can put a heat tape in the pipe, and while on vacation have someone come by and run warm water for a while. Alternately, you could install a small condensate pump that holds and discharges 2 gallons per cycle.
6. Keep all types of vehicles and high traffic people activities off of the system. This is a good rule to follow year round.
7. Make sure all risers; inspections pipes and manholes have covers on them. Sealing them and adding insulation is a good idea. Insulation may be added during construction particularly if the top of the septic tank is within 2 feet or the surface.
8. Keep an eye on your system. If any seeping or ponding occurs contact an onsite professional to help determine the cause and remedy.
9. If these steps fail to solve a freezing problem, you may need to dig up the area where the system is freezing to determine if there is a problem with the slope of the pipe.

For More Information

Please see our website at: http://septic.coafes.umn.edu/homeowner/index.html for more information about proper operation of septic systems. Otherwise give us a call at (800) 322-8642.